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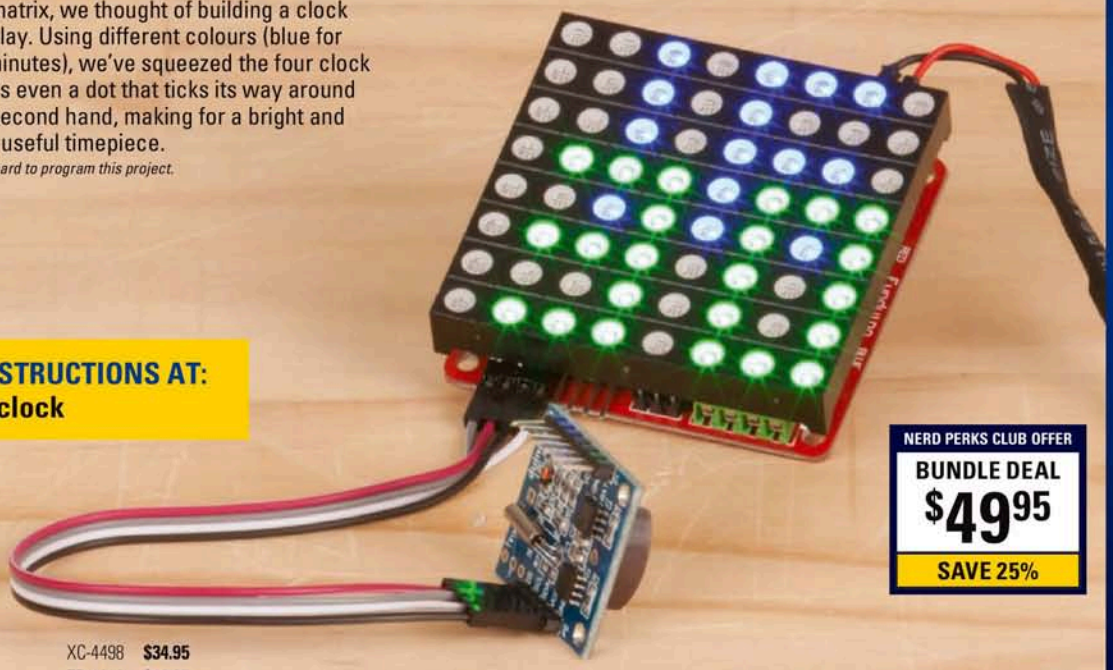

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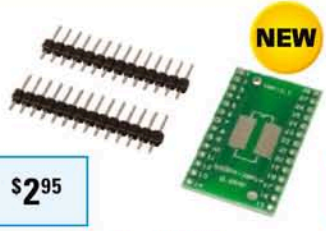

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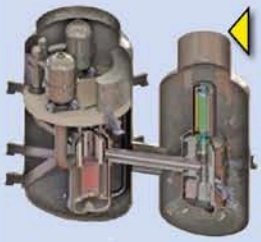

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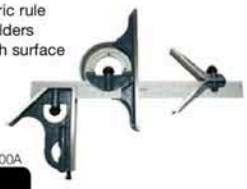

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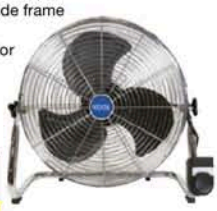

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Editorial Viewpoint

Got a project idea? There'll be a badly designed app for that!

In thinking up ideas for projects to publish in SILICON CHIP, we have a lot of hurdles to overcome and they seem to be multiplying.

Increasingly, we face the challenge of coming up with designs that aren't already available commercially (eg, from China) for less than the retail cost of the parts. We also have to consider the availability of smart phone apps which purport to do a similar job.

But while there is often an "app for that", it usually turns out to be a bit of a joke. For example, while working on the Earthquake Early Warning project published this month, we decided to try out a few earthquake alert apps first.

One claimed to provide "earthquake early warning" but seems to rely mostly on alerts from the USGS Earthquake Notification Service which states: "*Information for earthquakes in the U.S. is generally available within 5 minutes; information for earthquakes elsewhere in the World is generally available within 30 minutes*".

Hmm. Getting a message 30 minutes after a quake does seem a little pointless!

Now, the app does claim that it uses your phone and others running the same app in the general area to directly detect and warn of earthquakes but since there haven't been any earthquakes in our area in the last couple of months, we have no way of evaluating its true effectiveness. What if nobody nearby is running the app? How do we know their earthquake detection software really works?

And this is not an isolated case. For example, we've long thought that pretty much all "sound meter" apps are generally useless since the microphone in your phone doesn't have enough dynamic range and isn't calibrated. And audio oscillator apps cannot be guaranteed to generate the frequencies you might select. You might hear a tone but it might be far removed from the frequency it purports to be.

This was driven home for me while watching an episode of the TV show "Top Gear" a few years ago where the host as the time, Jeremy Clarkson, attempted to measure the noise levels of three different cars using his iPhone. He got pretty much the same reading in each case (within 1dB); possibly because the microphone was being overloaded by the noise. And the app "sort of" works, while the microphone sensitivity is an unknown and therefore any measurements may have very doubtful accuracy.

Maybe this was a stunt; surely a TV show with a multi-million dollar budget could afford a proper sound level meter? But I wonder how many users of this sort of app realise its limitations?

Light meter apps also must be suspect. While seemingly useful, we have to wonder just how accurate they are; presumably they sample the light using the phone's camera and its accuracy will vary from model to model. And the apps rarely provide any information as to the reliability or precision of their readings. They could be spot on or way off. Unless you compare them directly to a calibrated instrument, how would you know?

Having said all that, some apps definitely are handy. For example, we've published circuits in the past to generate white noise, water sounds and so on but now there are free "white noise" apps which make such projects obsolete. And that's just one example that comes to mind.

So when you see a project in the magazine, know that we've considered all the above. And before you rely on any app, make sure you check to ensure that it can deliver what it promises.

Nicholas Vinen

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Lath-E-Boy wiring is dangerous as presented

I just received the January issue and as usual it was a great read! But looking at the schematic on page 39 for the Lath-E-boy, there is a very problematic scenario in the bottom right-hand corner. The wiring for the induction motor is the big concern.

As per AS3000, under no circumstances are you allowed to use the yellow/green wire for power. It is only to be used for earthing. On page 41, in the picture of the junction box, you can see the yellow/green wire connected to the blue wire.

Even if the motor is mounted to the machine which is usually metal you still have to earth the motor separately, in case the bolts come loose.

I know some electricians are using the yellow/green wire for switching. In doing so, the wire must be covered by heat shrink so everyone is aware that this is not Earth.

It is just easier (and safer) to use a 5-core cable (red, white, blue, black and yellow/green) with adequate wire size as you need the yellow/green wire to earth the motor anyway.

Please make your readers aware of this and publish a correction!

Thomas Siegmeth,
Camira, Qld.

Comment: Thanks for bringing this to our attention. It is a big No-No and we should have spotted it.

We are publishing errata on this in the current issue and we will change the motor wiring in the bottom right-hand corner of the above circuit: green/yellow to dark blue and motor earth to green/yellow. The online edition will have this issue fixed.

Lath-e-Boy reversal not suitable for all lathes

I have a warning regarding the Lathe-E-Boy Lathe Controller from the January 2018 issue (siliconchip.com.au/Article/10933).

Reversing a lathe such as a Tida which has a camlock chuck is fine but if an unwary person sets up a lathe with a screw-on chuck to be reversible, the chuck can easily wind off the spindle nose. Otherwise, I found it to be a very interesting article. Keep up the good work.

Ian Stewart,
Camberwell, Vic.

Some vehicles charge their batteries sporadically

Your recent project for a variable speed fan controller (January 2018; siliconchip.com.au/Article/10938) is a superb piece of simple electronics.

However, recent trends in vehicle electronic design have now caused a huge problem, namely that battery voltage regulation as we have known it over the past one hundred years is no more.

The latest Mazda 2 models do have an upper charge voltage of 14.6V. The actual voltage with the engine running varies between 12.0 and 14.6V. I once travelled 70km with a battery voltage of 12V, and had to garage the car with near flat battery! It can continuously vary around the 12-13V.

This means that designs such as the fan controller will not work as the low-voltage cut-out may never be exceeded for long periods. The dealer service division state that it is not a fault, just normal operation.

I contacted Mazda Australia but they will not answer any questions of any nature about this charging scheme and are very secretive about the whole matter.

Some auto repair technicians I know have struck the same problem and they are baffled and confused. I can't find any mention of this in the owner manual, nor do they mention it in their brochures. Would you consider doing a feature about this matter in your magazine?

H. Wrangell,
Elimbah, Qld.

Nicholas responds: we have noticed this in other vehicles too. Leo Simpson owns a Honda which sometimes does not charge the battery unless you turn on the headlights. Then it will always charge it. On the other hand, my car always charges the battery while it's

Bug fixes for Micromite Mk2

I have produced a new version of the Micromite Mk2 firmware, for both Micromite and Micromite Plus devices: V5.04.07.

This fixes a fairly serious bug reported by SILICON CHIP staff, which results in memory corruption when a function modifies the contents of an array of strings passed to it.

The new version can be downloaded from http://geoffg.net/micromite.html (scroll to the bottom of the page). You will need a PICkit 3 or Microbridge to upload it to the PIC32 chip.

I also received a report of LCD corruption when using the Explore 100 to drive the specified 5-inch touchscreen at higher CPU speeds (100MHz+).

It turns out that some LCDs don't like the pulse width of some of the drive signals while other seemingly identical screens will handle it just fine.

So I have produced a beta version, V5.04.08, also available at the above download link. This increases the width of the drive pulses and it appears to now work consistently on all 5-inch LCDs at all CPU speeds supported by the Micromite Plus (ie, up to 120MHz).

Geoff Graham,
Perth, WA.

Comment: thanks for these bug fixes. We have updated the downloads on our website and will program future batches of PIC32 chips that we supply with the latest (non-beta) firmware.

running, so the fan controller works fine.

We probably should have mentioned this behaviour in the article and stated that if your vehicle does not always charge the battery with the engine running, you will need to run the Fan Speed Controller from an ignition-switched supply line and set its low-battery cut-out threshold below the minimum expected battery voltage while driving.

While we do not like this scheme, it won't necessarily harm the battery. But as you say, having to park a vehicle with a near-flat battery is not great. What if you're about to go away for a couple of weeks? What if the weather is going to get a lot colder during that period? They must have designed the battery with enough capacity to still start the engine under these conditions... you hope.

Possibly it's a fuel-saving measure since constantly keeping the battery on charge will load the engine slightly. But we'd be surprised if the savings come to more than a few dollars a year and the savings would be negative if you had to replace your battery prematurely.

WiFi model railway control is already available

I agree with Martyn Davison's assessment, on page 13 of the January 2018 issue, that Digital Command Control (DCC) is "aged" technology. It is 40 years this year since it was first used to control model locomotives. DCC has not only aged, it has become cumbersome and increasingly expensive as it tries valiantly to meet increasing expectations of modellers.

As a former member of the NMRA's DCC Working group, I remember the pain endured attempting bidirectional communication with several ineffective solutions battling it out. The fact is that DCC runs at a bit rate between 4.5 and 9kHz – it's slow!

Leo Simpson's reply expresses doubt as to the ability of Bluetooth or WiFi to replace DCC despite Martyn pointing out that Bluetooth model railway control is already being marketed. Martyn and Leo are both apparently unaware of recent developments in WiFi control of model railroads.

SILICON CHIP had an article in the December 2013 issue on the ESP8266 WiFi server (siliconchip.com.au/Article/8194). These are small and cheap; a complete WiFi server the size of a postage stamp! As soon as I read it, I realised my dream had come true.

With the help of my son (doing the programming), I built a prototype that fitted into an HO diesel locomotive. It was ugly, comprising an ESP WiFi module, H-bridge module and a driver IC. The same circuit built on one board by a machine would be similar in size to a DCC decoder.

It worked. Fellow Victorian NMRA members with little instruction could select the Loco's WiFi identity on their phone, open a browser and view a web page stored in the WiFi server within the loco itself. Pressing buttons on the page controlled direction, speed, lights, horn(s) and uncoupling.

With WiFi, many things are possible and most are already in use – bidirectional communications is standard, sound and video achievable.

The same machine that makes DCC decoders in China could make WiFi controllers at the same price. It should be half the price though, as the controller module could be used for many Internet of Things projects outside the model railroading hobby.

Having worked towards standards all my life, I felt a simple standard was required to ensure universal control between manufacturers. I contacted the technical department of the NMRA. They weren't interested, being currently bogged down with another cumbersome technology – the Layout Control Bus, DCC-compatible of course.

Manufacturers had invested in LCB and had a vested interest in keeping DCC. It was this manufacturer control of the NMRA that caused me to leave the DCC working Group in about 2001.

I started my own working group, find it at: siliconchip.com.au/link/aaj0

A number of modellers joined the working group. Unfortunately, about half of them were there to destroy the project. Vested interests in the US saw Direct WiFi Control (DWiC) as a direct threat to their business. It is.

All you need is a $20 controller for your loco and a phone, tablet or PC. The loco will run on DCC track, DC, AC or battery. There's no need for expensive command stations, boosters or a plethora of other accessories – the source of a DCC manufacturer's profit.

Meanwhile, my son and I had completed the prototype, proved the technology, and sat back and waited for a manufacturer to seize the opportunity.

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Well, one has, and his business is in Australia; see www.wifitrax.com

DCC took 10 years from its introduction to the NMRA in 1990 till its general acceptance in about 2000. Hopefully, DWiC will not take as long to be accepted.

Bob Backway,
Belgrave Heights, Vic.

Error introduced in editing letter

I note that you have edited my letter, titled "Instantaneous electric water heaters technology of the 1940s", on pages 10-11 of the January 2018 issue. Where I stated that the heater was connected "across phases", this was changed to read "across the three phases".

I should have said that they were connected between two of the three phases of the supply, as the only connection points were (1) to the body of the heater and (2) to the carbon electrode. There was no place to connect a third phase.

These heaters did not suffer from the "slow flow dropout" problem common to the three-phase models, as they would continue to draw current as long as any water was present to provide a path between the carbon electrode and the body.

Indeed it was possible – although unwise – to reduce the flow until the water boiled, resulting in jets of steam from the outlet.

G. D. Mayman,
Sturt, SA.

Comment: thank you for clarifying this.

Proposed NZ trams use supercapacitors

I have just finished reading the January 2018 issue of SILICON CHIP. There are once again very interesting articles about electric and autonomous vehicles. You may be interested in a story published in the New Zealand Herald on December 20, 2017 regarding the proposal for trams in Auckland. See: siliconchip.com.au/link/aaiv

At the moment, there's a lot of debate about introducing trams between the Auckland CBD and Auckland International Airport. We have traffic congestion just like Sydney. With the population increase in Auckland, it is adding an extra 800 cars per week to our roads.

Keep up the good work.

Graham Street,
Auckland, NZ.

Comment: charging a supercapacitor bank at each station is an interesting idea. One hopes that the tram doesn't encounter any unexpected obstacle which causes its bank to become discharged before reaching the next station! Perhaps an onboard emergency backup power source would be a good idea.

Speaker for the Super-7 AM radio is sold as a 5-inch unit

In the January 2018 issue, P. C. of Woodcroft, SA complains about not being able to source a suitable 4-inch speaker for the Super-7 AM Radio (Ask SILICON CHIP, page 94). I had the same trouble until I considered the Jaycar 5-inch round speaker, catalog code AS3007.

This unit must be the one intended by the design because it fits onto the PCB perfectly and looks identical to the speaker in the prototype photograph. The difficulty has arisen because a 4-inch speaker is specified in the parts list whereas Jaycar regard the AS3007 as a 5-inch unit.

Russell Howson,
Bronte, NSW.

Motor start capacitors degrade over time

Based on recent experience, I wonder how many whitegoods finish up in landfill for the sake of a $5-10 part.

I recently had the impression our freezer was "hard-starting". Measuring with SC's Energy Meter (upgraded using Geoff Graham's firmware) showed a starting power of 1500W averaged over the one second update period – this for a device that draws only 100W when running!

Further investigation showed the compressor was driven by a permanent split-capacitor motor and the run capacitor, labelled as 4µF, had dropped to a measured value of only 0.5µF.

A replacement capacitor, purchased from either element14 or RS components, measured 4µF and dropped the start power to 600W. That's still a lot but at least more reasonable.

So, went on to check (then fix) the fridge, where the capacitor had dropped from 4µF to 2µF and this had halved the starting current.

Ian Thompson,
Duncraig, WA.

Leo comments: We suspect that faulty motor-run capacitors are the reason many appliances with induction motors are discarded. Just recently I found that my pool pump motor was reluctant to start and it occurred to me that the bearings might be dry and needing lubrication.

However, at around the same time, a reader I was trying to assist (with problems with our Induction Motor Speed Controller) found that his problem was caused by a faulty motor run capacitor; down from 25µF to 17µF.

I duly checked my pump (as part of a sand filter re-install) and found that its run capacitor had dropped from 20µF to 13µF. I replaced it with a capacitor from Jaycar (Cat RU-6606 @ $16.95) and that fixed it.

Incidentally, both Jaycar and Altronics have a small range of suitable motor-run capacitors but they erroneously list them as "motor-start". The good thing is that Jaycar and Altronics stores are open seven days, which is great for "weekend warriors" – that probably applies to most DIYers.

Sewer Pump Sentry design proposal

I'm writing to you today to present a project article idea for a "Sewer Pump Sentry".

Years back I was having trouble with my sewer system; in particular the pump. On one occasion, the pump impeller got jammed by a foreign object and the motor burned out. On another occasion, when the septic field froze, the pump couldn't empty the tank and never stopped running until it burned out. This kind of event often causes a sewer backup which is no fun and often expensive to deal with.

As a solution to these issues, I designed and built a microprocessor-based system to monitor the sewer pump motor current and runtime. Should the current be excessive or the pump runs too long, my monitor produces an alarm.

Initially I had to measure the pump current outside the house, at the sewer pump electrical outlet, since the pump was not on a circuit by itself. This introduced additional problems in that the enclosure for the monitor had to be weather proof and the circuitry had to operate at potentially -40°C.

In addition, when an alarm condition exists, how is it announced and noticed when it's out of the house? The solution I found for this was kind of clever (I think). A 60Hz intercom was modified so that the call function could be activated by the micro. This

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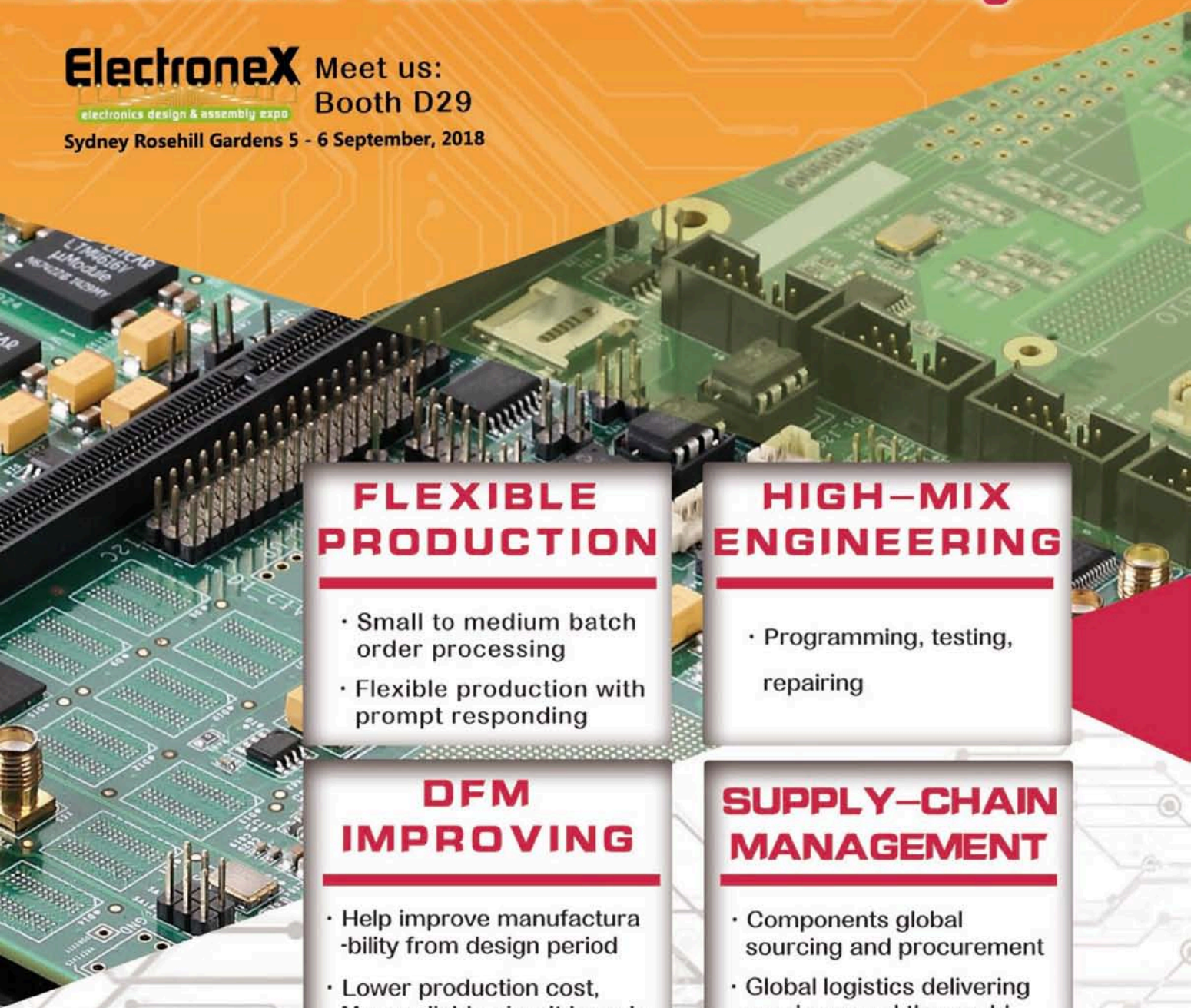

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meant that the alarm could be heard in the house and in more than one room.

This project has been running for about 10 years now and has been (for me anyway) one of the most useful things I have built. Just last week it warned me of a toilet that hadn't stopped flushing. So, that's my project and proposal. Do you think you folks would like to publish my project?

Gordon Dick,
Alberta, Canada.

Comment: thanks for sending us your circuit. It seems fine but we already published something quite similar. That project is the 230VAC Cyclic Pump Timer from the September 2016 issue, by John Clarke. It also monitors the mains current drawn by a pump and switches it off if it runs for too long.

While it doesn't have provision to switch the pump off if the current is too high, it does include a mains fuse which should blow in this case (if sized correctly), preventing the pump from burning out.

That just leaves the issue of how to sound the alarm in either case. The Cyclic Pump Timer has a fault LED but this will not switch on if the fuse blows. We will consider updating that project to include an alarm which will sound either when fault LED3 lights or fuse F1 blows. Your idea of using an intercom to make it audible inside your house is a good one. A wireless doorbell could also be used.

Custom case for Equaliser and VU Meter looks great

I wanted to share with you my realisation of putting the 10-Octave Graphic Equaliser (June-July 2017; **siliconchip.com.au/Series/313**) together with the Stereo LED Audio Level/VU Meter (June-July 2016; **siliconchip.com.au/Series/301**).

You published a photo of the custom case I used to build my Ultra-LD Mk.3 amplifier and CLASSiC DAC on page 16 of the June 2016 issue. So I decided the equaliser/VU Meter combination should go into a similar case that would stack with those.

My top criterion was the look of the enclosure. It had to be neat. I used the same construction as before – a 10mm aluminium faceplate, 2U enclosure. I used your two PCB layouts to design the front panel drawings with Adobe Illustrator and provide .dxf files to the manufacturer.

The equaliser part was the most straightforward with only the holes for the linear pots and the power LED. For the Stereo VU Meter, I had several choices of design:

- a rectangle hole to encompass the area with 80 LEDs, with a Plexiglas sheet between the PCB and the enclosure faceplate, or
- two rectangles, corresponding to each channel with the same Plexiglas sheet behind, or
- replacing the SMD LEDs with 3mm through-hole LEDs and drilling 80 holes. This solution had my favour initially, although desoldering the LEDs would have been tedious, or
- milling one rectangle and inserting a piece of Plexiglas inside (since the faceplate is 10mm thick). That would have been nice, but I was afraid the light conveyed from the LEDs would not be seen as individual light spots, or
- milling individual holes for each LED with an individual Plexiglas insert to "bring" the light from the LED to the faceplate. I thought this would be the best solution.

So I looked for Plexiglas cutting services and specified 2 x 6mm rectangular pieces (pretty much the size of the LEDs).

I needed around 12mm between the faceplate and the PCB. But they cannot cut a 12mm thick sheet. So they cut a 2.54mm thick sheet to 6 x 12mm instead and I used these pieces side-on.

But one important point had to be taken into consideration: the milling bit cannot make perfectly square holes in the aluminium plate. There was a radius for each cut in the aluminium. So I asked the cutting guy to round the corners of each Plexiglas piece.

When the enclosure came back, I was pleased as the two PCBs fitted exactly right. Indeed, space is very tight behind the faceplate! Everything was perfectly aligned.

One challenge for the enclosure manufacturer was that each hole was specified as 2.54 x 6mm: rather small to mill in 10mm thick aluminium. So they had to mill the back of the faceplate by 8mm to facilitate the usage of a small drill bit – making the holes actually 2mm deep.

When the Plexiglas pieces came back, their corners were rounded but not as I expected! I should have thought about it harder before. Since the sheet was 2.54mm thick, the rounded corners were those around the 6 x 12mm face and not the 2.54 x 6mm face.

So I had to file the corners of each piece with my Dremel. Eventually, I inserted the 88 pieces into their respective holes. Friction held them in place quite nicely.

One more criterion on top of the look was that I wanted the unit to be powered on and off together with the amplifier (my wife would have complained about one more button to push!). So I ran the power supply from the AC plugpack to the amplifier switch then back to the enclosure. It works well.

As I said in my previous letter, I no longer have any noise from the shared power supply, as the units are independently powered after the mains switch.

I'm including a photo of my set-up now. I am very happy with the final result. The light of each LED is well separated from its immediate neighbour. The VU Meter is connected directly to the amplifier speaker outputs at the back.

Thanks and keep up the good work in the magazine!

Olivier Aubertin,
Singapore.

Comment: we think this is an outstanding result, well done!

Hot Water Systems article criticism

I have been waiting for someone else to advise you that your recent article on adjusting hot water system thermostats (October 2017; siliconchip.com.au/Article/10834) should either be retracted or, at least, heavily qualified; it looks like it's up to me.

There is a reason why such thermostats must work at 70°C or higher. It's to prevent Legionella bacteria (of legionnaire's disease fame) from growing in the hot water tank. A quick internet search will support this.

There is also a requirement to reduce the temperature of the water to less than 55°C at the outlet. This being to reduce the risk of scalding. This requirement is usually met with the use of a "tempering valve" that mixes cold water with hot water at the system outlet.

In summary, that water is heated up then cooled down as required. I haven't researched it but I'm pretty sure that this situation is legislated and that anyone messing with it is open to action from on high.

By the way, I consider SILICON CHIP to be one of the finest magazines there is.

Peter McAulay,
via email.

Leo responds: no-one else has sought to comment on the veracity of the article and I believe that I adequately covered both the dangers of Legionella and tempering valves in the article. I read a number of current health and safety papers and regulations while I was writing the article, so I think it is technically correct.

You can argue about whether the minimum temperature in a hot water tank should be 60°C or 65°C but 70°C is far too hot and it wastes energy.

While I did not specifically mention it, many hot water systems are close to or actually in home laundries. That can mean there is a significant risk of scalding from the hot water tap over laundry tubs. Arguably, a tempering valve could be fitted in these circumstances.

One of the main reasons I wrote the article is that many hot systems are simply set far too high, with the attendant dangers of scalding of infants and older people. In only takes two seconds exposure to hot water at 60°C to cause scalding.

I have grandchildren and I have seen first hand how they can turn on the hot water tap while they are cavorting in the bath. In almost the blink of an eye, they could have been scalded if the temperature was at 60°C.

Instances of scalding are quite common while Legionella in hot water systems is fairly rare, although it is fairly common in air conditioner cooling towers in large installations.

Article on inverter generators wanted

Firstly, thanks for a great publication that I look forward to receiving each month. Could you please do an article on inverter generators?

I have been looking at buying a small generator and have been overwhelmed by the range available and the claims made. I like many others do not trust the power grid and want some personal backup power at home. Some of the factors I have been presented with include.

- inverter generators will carbon up the cylinder if run too long on a light load because the revs vary with the load (including Honda generators, which are regarded as the benchmark).

- cheap inverter generators are not suitable for powering electronic loads – only the more expensive inverter units are suitable.
- all inverter generators claim to have a "pure sine wave" output – is it a better sinewave than a standard generator?
- does the output of an inverter generator have lower harmonic content than a standard generator?
- inverter generators have an advantage in weight and portability.
- the small profile of inverter generators might become a problem with heat dissipation at high load (high revs).
- how is protection earthing achieved with an inverter type? Standard generators have the earth conductor bonded to the neutral conductor inside the generator in order to complete the fault circuit path to trip the protection during a fault.
- motor starting ability – most inverters are rated for peak and continuous watts. Their motor starting ability is vague at best. It would appear that standard generators have better motor starting ability due to rotational inertia.
- some inverter generators have paralleling kits available (which I think is not much use to a homeowner wanting small loads during a blackout).

It would probably be good to include something on the danger of powering the house through a male/male extension cord powering the house back through a power point. A common practice as I understand it.

I look forward to any future article on generators.

John Lean,
Orange, NSW.

Comment: we will consider publishing an article on inverter generators but this would be a big undertaking.

Carbon build-up is definitely an issue for internal combustion engines that never run near red-line or at full load. This can usually be fixed by purposefully loading the engine for a few minutes (eg, by plugging in a radiator) which will burn off or blow out the carbon build-up. When done with a motor vehicle, this is known as an "Italian tune-up"!

Most electronic loads don't need a sinewave to operate properly. Even a square wave with the appropriate voltage is fine. That's why most UPS devices, designed to power computers and such, do not produce a sinewave output.

The main reason why electronic loads would challenge an inverter would be the high inrush current but this can be mitigated with a soft starter (as published in our April and July 2012 issues).

You may also be able to use a Soft Starter to improve motor starting, depending on the type of motor. The speed controller on page 34 of this issue would definitely help if you're running power tools from an inverter (assuming they aren't powered by an induction motor).

The earthing arrangement for an inverter generator should be similar to any other generator.

A non-inverter generator likely would have a fairly pure output off-load but the sinewave will distort under heavy load. That's less of an issue with inverter-based generators.

So we would guess that the waveform from an inverter generator under load would have lower overall harmonics.

But most loads are not terribly sensitive to this. Consider that the mains already has fairly high distortion (up to a few percent).

Problems loading Arduino sketches

Thanks for the interesting article on barometric pressure sensors in the December 2017 issue. I purchased the code for the Arduino and installed the SFE_BMP180 Library. I renamed the library folder to match the library name in the sketch.

However, the sketch would not compile and I have sent a couple of pictures to show the error (SFE_BMP180 does not have a name type). I am using Arduino 1.0.5 r2 which I have never had any trouble with

I got the same error on sketches downloaded from the Elecrow site as well.

I eventually managed to solve the problem, as follows. I'm not sure why but the zip file I got was called "BMP180_Breakout_Arduino_Library-master." The Arduino IDE didn't like that so I changed the folder name to "SFE_BMP180".

The IDE liked this and allowed the library to be installed but the sketch still would not compile. Upon opening the library folder I found another folder named "src". The header and .cpp files were in that folder instead of the main folder.

I copied them into the main library folder "SFE_BMP180" as above and Bingo! Maybe I downloaded the library from somewhere else other than your recommended link.

It is worth passing this onto other readers as I have experienced other library folder names not matching the include statement in the sketch.

It is also worth checking that the .h and .cpp files are visible in the first folder when you open the library. This causes a fair bit of frustration but is great once you finally solve the mystery.

On another Arduino-related subject, I had trouble some time ago with the Arduino sketch for the GSM Remote Monitoring Station from the March 2014 issue. See **www.siliconchip.com.au/Article/6743**

The sketch refused to compile on IDE 1.8.1 and I found that when I tried it again on 1.0.5 r2, it worked. Hopefully, these pointers may stop someone else going mad.

Geoff Coppa,
Alstonville, NSW.

Comment: unfortunately, the link given in the article for the SFE_BMP180 library no longer takes you to a page with a direct download link for the library. We think this is the source of the confusion.

*You are right that the .h and .cpp files should be in the main directory of the Arduino library or it will not work. A forked version of the original library that will install directly can be found at **github.com/LowPowerLab/SFE_BMP180***

Clicking on the "Clone or download" on this page and then "Download ZIP" links yields a library with the files in the right places.

*The original library can be found at **github.com/sparkfun/BMP180_Breakout** and **github.com/sparkfun/BMP180_Breakout_Arduino_Library***

Comments on past issues

In regards to the January 2018 editorial by Nicholas Vinen on autonomous vehicle security: driverless cars will be far safer if their driving computer is fully air-gapped.

CPUs are so cheap that any ancillary service(s) should have their own system and not potentially compromise the driving computer.

Secondly, the driving computer must not be proprietary/closed so a user can be assured that there are no "back-doors" nor outside control.

The business models of the likes of Apple, Microsoft etc cannot be trusted to implement this. A recent example is Apple deliberately interfering with the iPhone's speed.

Then there is the issue of governments' control/interference! The most dangerous component of a car is the nut that holds the steering wheel. The fact is that 99% of accidents are due to human (driver) error.

Regarding the November 2017 Dipole Loudspeaker System (siliconchip.com.au/Article/10865); I love the concept and innovation (and the potential to reuse old speakers). But looking at it makes me wonder if it could be rationalised further. How about using power line networking?

The signal generator then does not need to be near anything and you can put the rest in the speaker. The speakers still require both signal and amplification/power which can then be done from one plug anywhere in the house.

Woofers which have different/bigger amplifier requirements could be easily separated out and extras added as desired.

Raspberry Pis are so cheap that they can easily be used in each speaker to digitally manipulate/filter the audio frequencies before converting to analog. Are there any non-proprietary power line networking "El Cheapo Modules" for such a project?

Regarding the October 2017 article on setting hot water thermostats (siliconchip.com.au/Article/10834); the nuisance I've noticed with tempering valves is a reduced flow rate where they've been installed and the complete loss of really hot water in situations where it is wanted (eg. dishwashers, laundry etc).

Regarding the September-October 2017 Fully Adjustable, 3-way Active Loudspeaker Crossover project (siliconchip.com.au/Series/318); this project seems to be half a step away from being a simple surround sound decoder. Perhaps a revised project implementing this improvement would be worthwhile.

J. Williams,
Elanora, Qld.

Comment: we agree that air gap security for autonomous vehicles would vastly reduce the chance that they could be compromised but it would also severely limit their usefulness.

They would not be able to download updated maps or software. These could only be updated during a service and even then, the update process could potentially be compromised and malware could be installed without your knowledge.

Tesla already sell semi-autonomous vehicles and they are definitely not air-gapped. In fact, the autonomous capabilities were added to vehicles that were already in customers' hands and they didn't have any say in the matter.

We're not sure that adding an audio-over-power-line interface to an active loudspeaker system could be considered rationalisation.

It surely is technically possible but would require some fairly complex hardware and software.

Ethernet-over-power adaptors are not terribly expensive and could certainly be teamed up with Raspberry Pis, or any other single-board computer with an Ethernet port. WiFi seems like it would be easier and cheaper, though.

Tempering valves are not normally installed in kitchens or laundries. They are primarily for use in bathrooms, mainly in showers and baths.

These types of valves can also result in some feedback problems with instantaneous hot water systems, where the tempering valve lowers the hot water flow rate over time such that the hot water system starts to flow cold water and the tempering valve then increases the flow rate again and the cycle repeats.

Can satellites help locate missing aeroplane?

I enjoy reading your magazine through the library. I especially liked the article on Tiny Satellites in the January 2018 issue (siliconchip.com.au/Article/10930).

In view of the phenomenal numbers of satellites generally and their amazing capabilities, has anyone asked the question of the owners as to whether there were MH370 sightings when and where the plane was flying?

Is it naive to think that the answers lie within some multi-billion terabits of storage held somewhere?

Thanks for a great magazine.

John Cooper,
via email.

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EARTHQUAKE Early Warning Alarm

Concept by Allan Linton-Smith • Circuit and software by Nicholas Vinen

Earthquakes can strike anywhere . . . and usually with very little warning. But these days there are ways that you can get an early warning, that may be the difference between getting to safety (eg, an open area) and possible injury or death. So how do you go about getting early warnings of impending earthquakes? Read on...

Probably the easiest way to get earthquake warnings is to install an early warning app on your smartphone.

The idea is that a network of seismographic sensors based around the world will pick up an earthquake soon after it occurs and determine its location (based on triangulation), depth and magnitude.

The app receives this data within seconds and compares it to your location.

Depending on your proximity to the earthquake and its magnitude, it can generate an alert, seconds or even minutes before the destructive waves of the earthquake arrive.

But this does rely on a few things working properly: you have to have a smartphone, it has to be charged and switched on, it has to have a working internet connection, the app needs to be installed and running properly.

And there's also the fact that, depending on where the seismic sensors are located geographically, signifi-

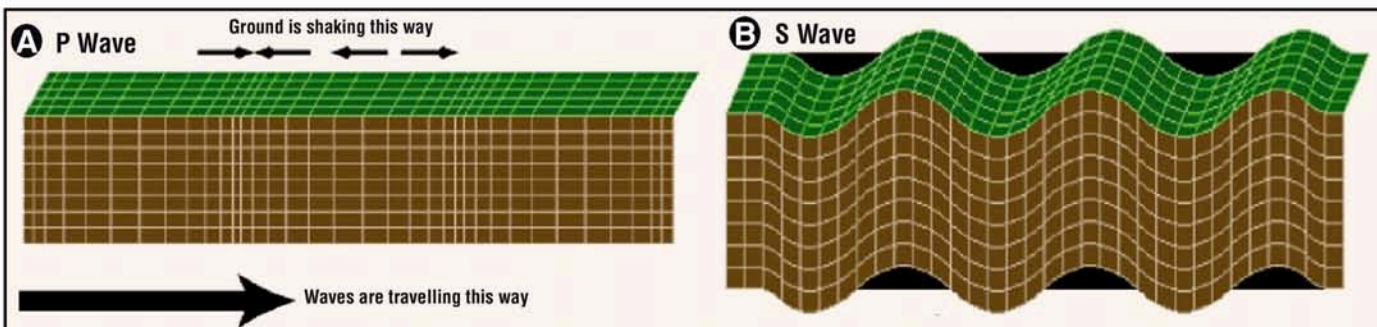


Fig.1: the four different waves caused by an earthquake. In order of fastest to slowest, (a) the P-wave is a compression wave, (b) S-wave is up-and-down and/or side-to-side motion.

A commercial earthquake early warning alarm, the FREQL (Fast Response Equipment against Quake Load), used by rescue teams in earthquake areas. Ours is very much simpler . . . and cheaper!

Here's another commercial detector – the Chinese-made XYB01A. It's not intended for first-responder use; in fact, it's designed for home use, mounting on a wall as shown. We found it tricky to set up and use.

cant time could pass before the alert is even raised.

We installed some popular earthquake early warning apps and set them up to warn us about earthquakes around the world. (There are, literally, hundreds of earthquakes occuring every day – only the largest make the six o'clock news . . .)

Timing!

We found that we sometimes got alerts many minutes after an earthquake had occurred – somewhat pointless, you'd agree!

Of course, even if the warning is timely, you might not hear the alert or you may not look at the screen straight away.

But there's another option and it may be much more useful, because it doesn't rely on remote seismic sensors, an internet connection or any software.

And you don't even need to own a smartphone.

Early warning using P-waves

Earthquakes cause a disturbance in the Earth's crust that you can feel. They are generally caused by a sudden rock fracture where the pressure has built up at the junction of two tectonic plates, due to continental drift.

When this energy is suddenly released, it causes waves to travel through the Earth's crust away from the location of the fracture.

You may not realise it but a single seismic event can cause at least four different waves to travel through the Earth and shake the ground beneath your feet.

Unless you are very close to the epicentre, these waves will arrive at different times and they will have different strengths and effects.

The first wave to arrive is the pressure wave or P-wave. This travels in a similar manner to the way sound travels through air – see Fig.1(a).

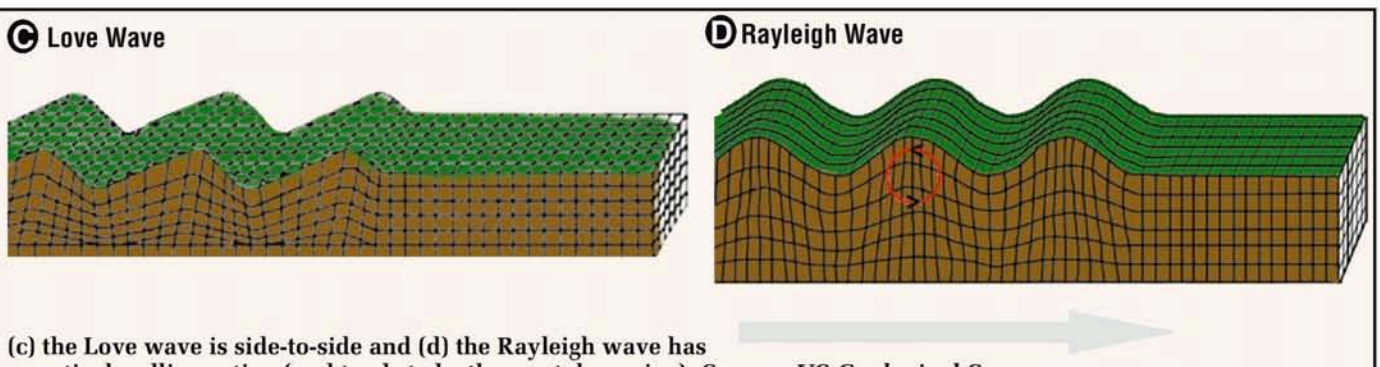
Part of the reason why it arrives first is that it can travel through solids and liquids, so it can take a direct path through the Earth to your location (ie, it doesn't have to follow the curvature of the Earth, despite the fact that there are liquid layers under the Earth's crust).

The P-wave is usually not terribly strong nor destructive but it certainly can be detected using seismic monitoring equipment and this will give you the most warning before the destructive waves arrive at your location.

The secondary wave is known as the S-wave and this is caused by rock particles moving side-to-side or up and down, similarly to the way that a wave travels through deep water – see Fig.1(b). Because the S-wave cannot travel through liquid, it can not pass through the Earth's outer core and so generally arrives after the P-wave. It is usually strong enough to be felt but is not the most destructive wave.

The third wave to arrive is the Love wave (named after A.E.H. Love) – see Fig.1(c). This is the fastest surface wave and is caused by the surface of the Earth moving side-to-side.

Because it has to travel along the surface, it takes the longest path and therefore arrives after the S-wave and P-wave.



(c) the Love wave is side-to-side and (d) the Rayleigh wave has a vertical, rolling action (and tends to be the most damaging). *Source: US Geological Survey.*

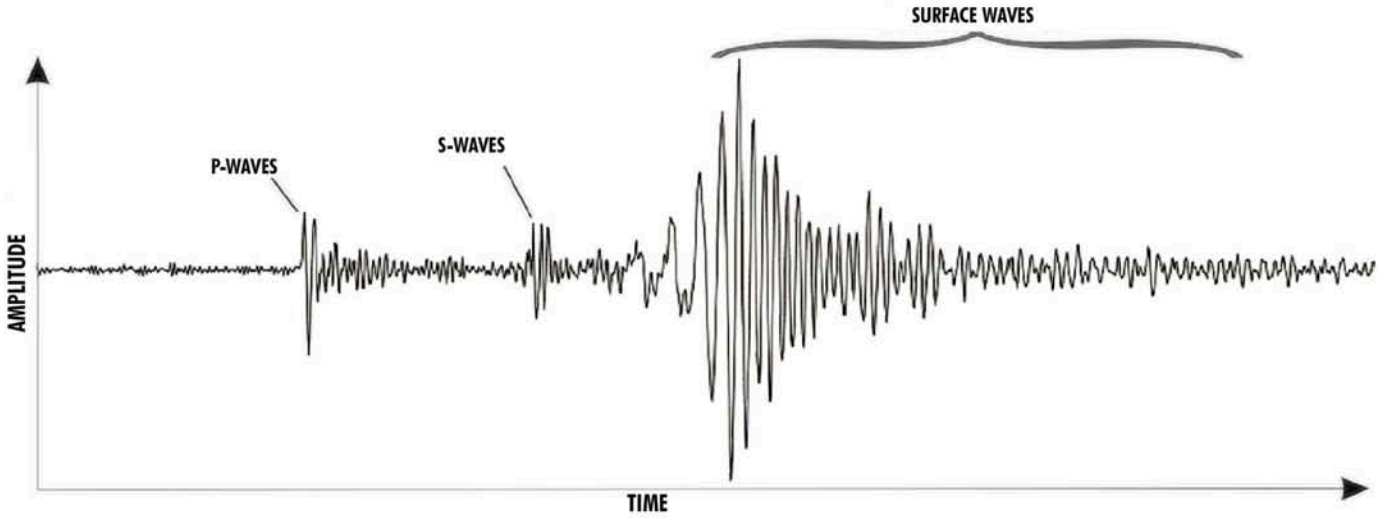


Fig.2: a seismograph plot taken some distance from an earthquake, showing that the P-waves arrive first, then the S-waves, then the surface (Love and Rayleigh) waves.Typically, the surface waves have the greatest amplitude and will be the most destructive. Source: US Geological Survey.

Shortly after the Love wave comes the Rayleigh wave, which also travels along the surface. It causes vertical motion as the ground "rolls", much like waves in shallow water – see Fig.1(d). This is the wave which is normally felt the most and causes the most destruction.

The relative speeds of the P-waves, S-waves and surface waves can be seen in the seismograph plot of Fig.2. Fig.3 gives more detailed information on the relative speeds of P-waves and S-waves while Fig.4 shows how the P-waves and S-waves travel at different speeds through different parts of the Earth's crust.

Notice though that the P-wave velocity is always higher than the S-wave velocity, so in most cases it will arrive much earlier.

Fig.3 shows how long a typical P-wave and S-wave take to reach a certain distance from the epicentre. As you can see, the S-wave takes around twice as long to reach a given point compared to the P-wave.

If we can detect the passage of the P-wave, then the interval between these two lines is the amount of warning we get before the larger S-wave arrives.

For example, if you are 200km from the epicentre, you would get around 30 seconds' warning while if you are 2000km away, you will get around five minutes' warning.

Unfortunately, the closer you are, the less warning you will get and the more destruction the earthquake will cause (as the waves drop in power as they travel away from the epicentre and expand).

For the most damaging 'quakes, you probably won't get more than one minute of warning.

Detecting the P-wave

Commercial P-wave detector devices do exist. One example is the port-

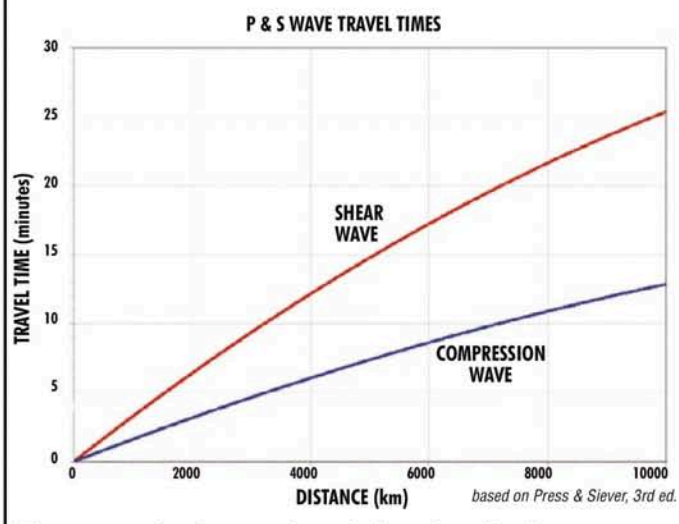


Fig.3: a graph of approximately how long it takes for the P-wave and S-wave to reach a point a certain distance from the epicentre. The P-waves travel about twice as fast as the S-waves so they reach the same distance in about half the time. The lines are curved due to the curvature of the Earth.

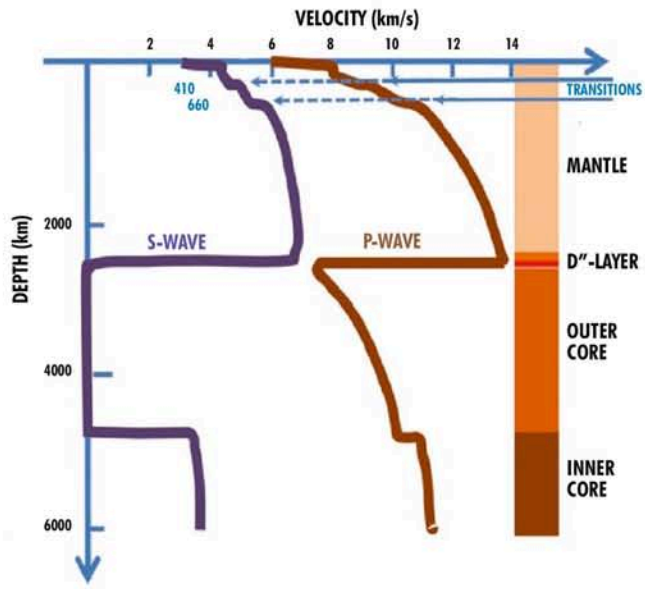


Fig.4: this shows how fast the P-wave and S-wave typically travel at various depths in the Earth's crust. The P-wave travels faster so it will arrive first.

able FREQL (Fast Response Equipment against Quake Load). This is used by rescue teams and fire departments in Japan and is especially useful for early warning of dangerous aftershocks during difficult rescue phases. It's shown overleaf.

You can also get consumer-grade devices such as the Chinese-made XY-B01A detector. This is a wall-mounted unit which runs from a 9V battery and uses a pendulum to make contact when a P-wave is experienced, sounding the alarm.

It is mechanically adjustable but is a little tricky to set up.

The P-wave normally has a frequency of between one and five hertz (1-5Hz) and could consist of just a short jolt, a series of tremors or a continuous wave, depending on the nature of the earthquake.

So to give you the best chance, the device needs to be as sensitive as possible to signals in that frequency range and with the correct orientation, without being so sensitive that it could be set off by other vibrations.

Our detector

The electronic device we describe here uses a relatively inexpensive but very sensitive accelerometer combined with a regular Arduino board.

Depending on where you live, it may give you enough warning to find a safe place if it detects an oncoming earthquake or aftershock. And it may be useful if you live near an active volcano; volcanoes can generate P-waves prior to eruption.

No promises, of course: but it's much better to have a detector which could give you warning than have no detector and have no chance!

Besides, it's cheap, easy to build and requires very little soldering. You can put it together in about an hour or so, even if you aren't very experienced.

We considered designing the device around analog circuitry but P-waves can come from any direction and thus some fairly intense signal processing is required.

This is much easier to do with software and it doesn't require a custom-designed PCB.

Circuit details

Our circuit is shown in Fig.5. The two main components are the Arduino Uno (or equivalent) board, MOD1, and the Altronics Z6324 digital accel-

The tiny MPU-6050 3-axis accelerometer which is the "heart" of the project, detecting distant P-waves.

erometer/gyroscope, MOD2.

MOD2 uses the MPU-6050 IC and we've chosen this one in particular because it has an on-board 16-bit digital-to-analog converter (DAC). Note that we aren't using the gyroscope feature, just the accelerometer.

At maximum sensitivity, the full-scale reading of this device is ±2g on each of the three axes and the 16-bit DAC means this has a resolution of 0.0006g [(2 ÷ 32768].

That's what we need to detect the very small vibrations of a P-wave from a distant source.

P-waves are often so faint that you can't feel them with your sense of touch but this device can potentially detect such small tremors.

One of the handy things about the MPU-6050 is that it has configurable digital low-pass and high-pass filters. The low-pass filter can be configured with a -3dB point of 5Hz, 10Hz, 21Hz, 44Hz, 94Hz, 184Hz or 260Hz. We have chosen 5Hz as this suits our application.

Similarly, you can configure it for a high-pass filter of 5Hz, 2.5Hz, 1.25Hz or 0.625Hz.

We have used the last option, giving a response of 0.625-5Hz. We provide an additional 1Hz high-pass filter in the software (which also helps to remove any residual gravity from the readings, eg, if the unit is not mounted perfectly horizontally).

The Arduino makes a couple of dozen readings of the X, Y and Z axis acceleration figures each second and after processing them, it uses an RMS

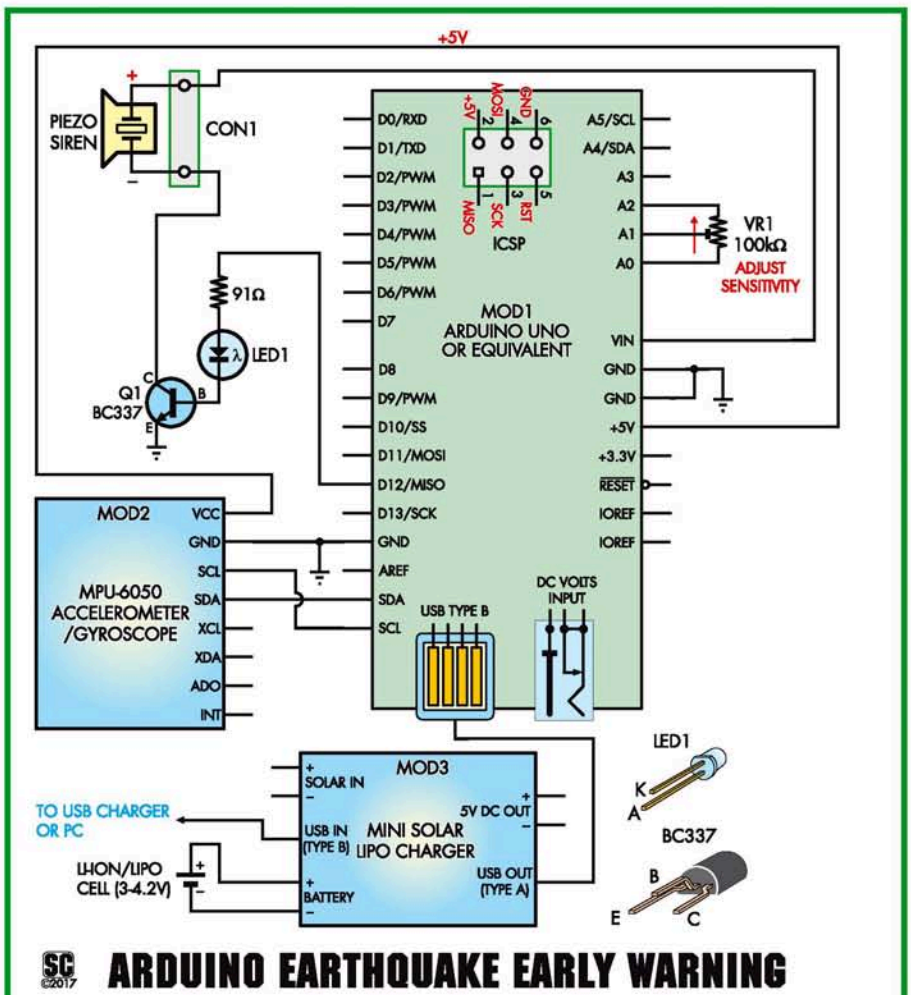
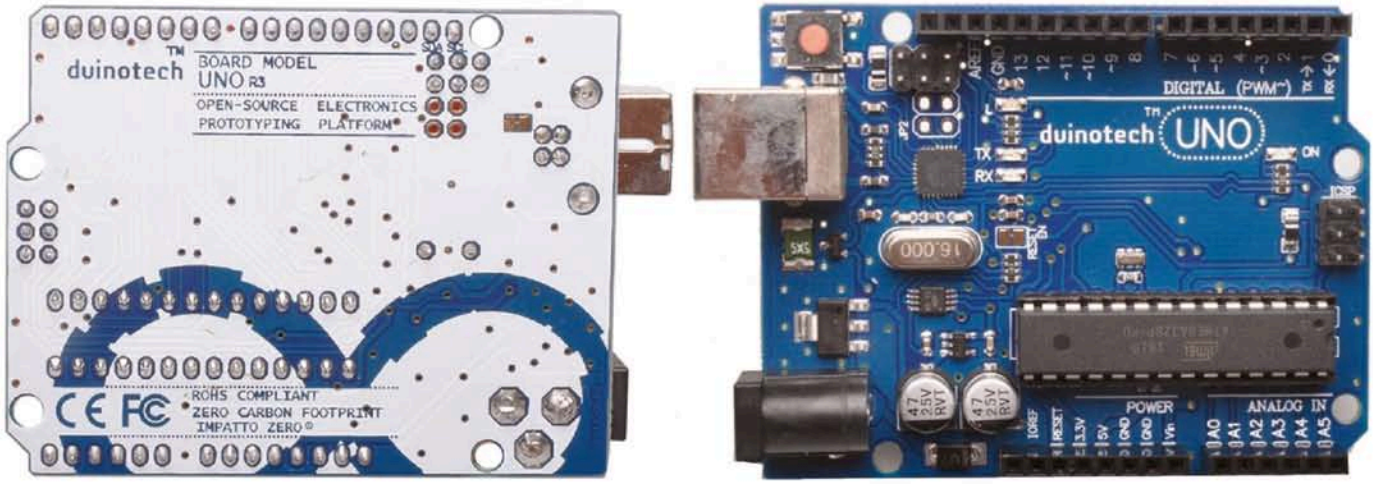


Fig.5: full circuit of the Earthquake Early Warning Alarm, including the components for the optional battery-backed supply, at bottom. The Arduino (MOD1) constantly reads the three acceleration values from MOD2, performs digital filtering and amplification, then decides whether to light up LED1 and sound the loud piezo siren.



The two sides of the Arduino Uno board, shown here close to life size (in this case the duinotech UNO from Jaycar – there are several compatible boards). The protoboard (opposite) simply plugs into the sockets on the edges of the board.

formula to compute the magnitude of the resulting X/Y low-frequency vector.

This is multiplied by a sensitivity factor, set using trimpot VR1, and if it exceeds an arbitrary threshold for more than about 200ms, the alarm is triggered.

To sound the alarm, output pin D12 is pulsed high and low at about 1Hz. When high, bright blue LED1 lights up and NPN transistor Q1 is switched on. This triggers the very loud piezo siren. Its volume and pitch are similar to a smoke alarm.

If an S-wave or surface wave is detected (by a similarly large excursion in the magnitude of the Z-axis measurement), LED1 and the piezo siren also light but they are on continuously, rather than pulsed.

This should alert you to the fact that you are currently experiencing an earthquake, in case the other signs (shaking, falling objects etc) are not obvious enough!

The unit can be mains-powered, via a USB port on a PC, from DC plugpack or the optional battery-backed supply (shown as MOD3 at the bottom of Fig.5) can be used.

This consists simply of a single Li-ion/LiPo cell combined with a small charger/power supply board. The battery is kept charged by the USB power supply when mains is present.

The battery can power the rest of the circuit for a few hours if there is a blackout.

While we haven't shown a solar panel connected there is provision for one – this could make the whole project fully self contained with solar-backed power if you wished to remotely use it. Virtually any 6V-12V solar panel could be pressed into service – the circuit only draws significant power from the battery when the alarm is going off . . . at which time a flattening battery is likely to be the least of your concerns!

To make construction easy, we wired trimpot VR1 directly to pins A0, A1 and A2. A1 is used as an input while A0 and A2 are programmed as digital outputs.

So we simply pull A2 high (to +5V) and A0 low (to 0V) just before measuring A1.

Therefore we read the position of the trimpot as a digital value and use that to determine the sensitivity.

This is computed exponentially so that the full range of rotation of VR1 gives about a 100:1 ratio between the level of vibrations needed to trigger the alarm at its two extremes.

We've set up the sensitivity so that at maximum, the unit will trigger on the tiniest tremor, while at the minimum setting, you'd probably have to hit it with a hammer to set it off.

Also note that to save power and simplify the circuit, we wired the warning LED in series with the base current limiting resistor for Q1.

The LED current is around 11mA [(5V-3.3V-0.7V)÷91Ω]. If you use a different colour LED, it will be driven at a slightly higher current, due to its lower forward voltage but it shouldn't be necessary to change the resistor value. (If you don't have a 91Ω resistor, 100Ω should be fine).

Construction

While you could build the device by wiring up the various components with flying leads, we used a protoboard to give a neater result, as you can see from the photos.

No component overlay is shown for the protoboard as there are so few components involved – all of the interconnection details are clearly shown in the photograph.

By soldering connected components close together, we only needed to run five wires, all of which you can see on the top of the board (two 0Ω resistors and three lengths of hookup wire; blue, green and red).

Wire links can be used in place of the 0Ω resistors if you prefer. (Wire links are also a tad cheaper!)

Start by soldering an 8-pin header to the MPU-6050 accelerometer module, then solder it to the prototyping shield.

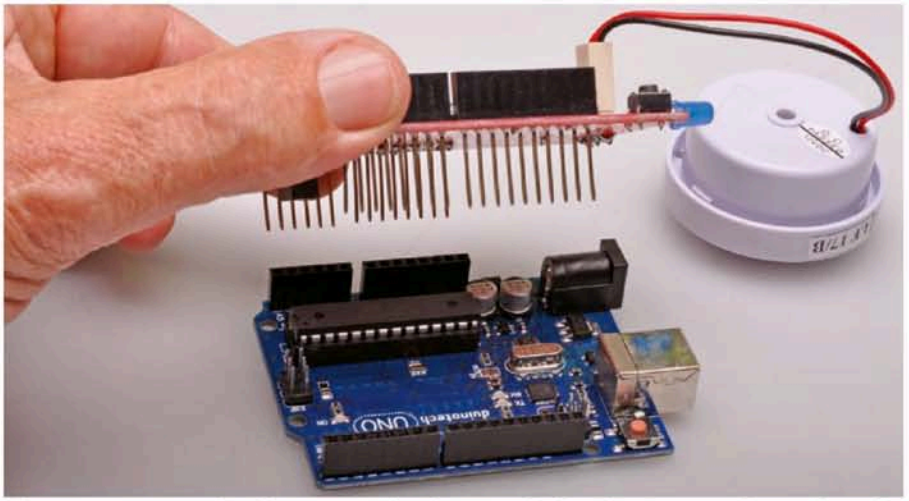
You will need to make four connections between this module and the shield headers: VCC to +5V, GND to GND, SDA to SDA and SCL to SCL.

Having done that, solder the 91Ω resistor from pin D12 to a pad near the edge of the board, then connect it to the LED anode. Connect the LED cathode to the base (middle pin) of Q1.

The collector of Q1 is the right-most pin when looking at its labelled face and this is connected to 5V. The remaining pin of Q1 goes to the negative pin of the piezo siren via CON1, with the positive pin wired to VIN.

We connected the piezo siren via a 2-pin polarised header. This is handy for testing since the siren is very loud,

If it's too loud while you're setting up, it can be temporarily muted by having something placed over its opening (a piece of sticky tape or insulation



The two PCBs simply plug into each other via the header pins on the top board and the matching sockets on the Arduino board, as shown here.

tape, for example) or placing it upside-down on your bench top.

If you don't want to solder the wires to a plug and the header to the PCB, you can directly solder the piezo wires to the board.

Finally, solder trimpot VR1 to pins A0, A1 and A2, as shown in the photo. That's it – those are all the connections you need. Solder the headers to the shield board, then put it aside while you program the unit.

Programming it

Download the Arduino sketch, named EarthquakeEarlyWarning.ino, from the SILICON CHIP website.

You will also need to have the Arduino IDE installed on your computer. The latest version can be downloaded for Windows, macOS and Linux from www.arduino.cc/en/Main/Software

Once it's installed, load it up and open the sketch.

There is one additional library that needs to be installed. It's called "Filters" and a zip file is included in the download package. Use the Sketch -> Include Library -> Add .ZIP Library menu option to install this file on your system.

Now plug the Arduino into your computer using a USB cable (without the shield, for now) and then go to the Tools menu and make sure the correct Port has been selected.

You can then use the Sketch -> Upload command to upload the code to the Arduino module.

Check the output at the bottom of the screen to make sure it has been compiled and uploaded without errors.

You can now unplug the Arduino module from your PC and plug the completed shield into it.

Then plug it back into your PC and open the Serial Monitor in the Arduino IDE. It's available under the Tools menu. Pretty soon, you should see an output like this:

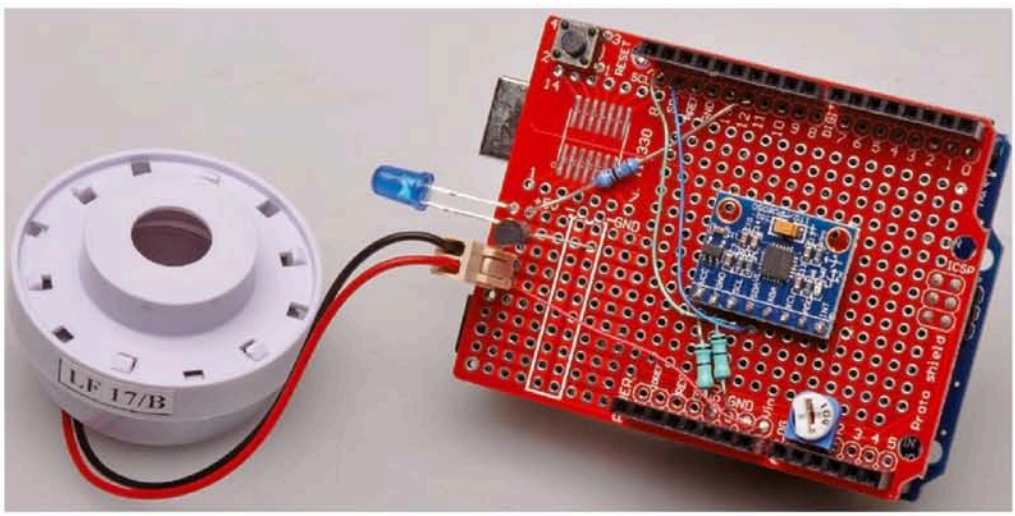
```
|XY| = 0.05, |Z| = 0.11
|XY| = 0.37, |Z| = 0.05
|XY| = 0.17, |Z| = 0.04
|XY| = 0.22, |Z| = 0.29
|XY| = 0.20, |Z| = 0.08
|XY| = 0.27, |Z| = 0.20
|XY| = 0.16, |Z| = 0.21
|XY| = 0.02, |Z| = 0.25
|XY| = 0.42, |Z| = 0.04
```

Parts list – Earthquake Early Warning Alarm

- 1 Arduino Uno or compatible board (MOD1)
- 1 MPU-6050 based accelerometer/gyroscope module with 8-pin header (MOD2; Altronics Z6324)
- 1 1-13V loud piezo siren (Altronics S6115)
- 1 Arduino prototyping shield PCB and header set
- 1 high-brightness 5mm LED (LED1)
- 1 BC337 NPN transistor (Q1)
- 1 100kΩ mini horizontal trimpot (VR1)
- 1 91Ω 0.25W resistor
- 1 2-pin polarised header and matching plug (CON1)
- a few short lengths of light-duty hookup wire
- 1 small plastic box (eg, UB5 Jiffy box)
- 1 USB charger or other USB power source

Optional parts for battery backup

- 1 solar charger module (eg, SILICON CHIP Online Shop Cat SC4308)
- 1 small single-cell Li-ion/LiPO cell
- 1 short USB cable to suit solar charger module
- 1 6-12V mini solar panel, if required



Here's the protoboard with the LED, transistor, resistor and trimpot plus the MPU-6050 accelerometer board all mounted, as per the circuit overleaf. This assembly plugs into the Arduino Uno. The two light blue "resistors" (bottom of PCB) are actually 0Ω links.
The piezo "siren" is rather loud, as you would want it to be if it is to warn you of impending doom!
Not shown here is the optional battery and recharger – see full details of this in the article in SILICON CHIP, August 2017.

These are the readings from the accelerometer. |XY| is the dimensionless magnitude of the horizontal AC vector while |Z| is the magnitude of the AC component of the vertical vector.

If you shake the unit, you should see these values temporarily increase, then settle back towards zero. Rotating VR1 clockwise should cause them to increase and with VR1 fully clockwise, even the slightest nudge should cause LED1 to light up and flash.

Assuming it's working, turn VR1 clockwise as far as you can go while ensuring that LED1 remains off when the unit is sitting untouched on a steady surface.

Note that the alarm condition persists for several seconds after any shock so you will need to make small adjustments and leave the unit alone for a few seconds to see whether the sensitivity is correct.

A cheap 6V-12V solar panel, as shown here, a surplus mobile phone battery (both commonly available on ebay) plus one of the small "Elecrow" Li-Ion battery charger modules (available from the SILICON CHIP Online Shop, Cat 4308) will make a fine power supply for your Arduino-based Earthquake Early Warning Alarm, with the added advantage of making it completely self-contained: no external power supply is required!

You can then plug the siren in and check that it sounds when you bump the unit.

Setting it up

Mount the unit inside a box so that it's held firmly in place within that box. The "noise hole" of the piezo siren (ie, where the sound comes out!) should line up with a similar hole in the box.

The orientation of the electronics don't matter, as long as when the device is mounted on a wall (the preferred location), the accelerometer PCB is horizontal.

The device should be firmly fixed to a solid wall and if set correctly, it will sound the alarm when it experiences significant horizontal movement in any direction. Since the wall should be solidly fixed to the ground, that normally will only occur if the ground moves.

We can't rule out the occasional false alarm due to heavy vehicles, trains, nearby hammer blows or similar but you can turn VR1 anti-clockwise slightly if you are experiencing false alarms, reducing its sensitivity until they stop. SC

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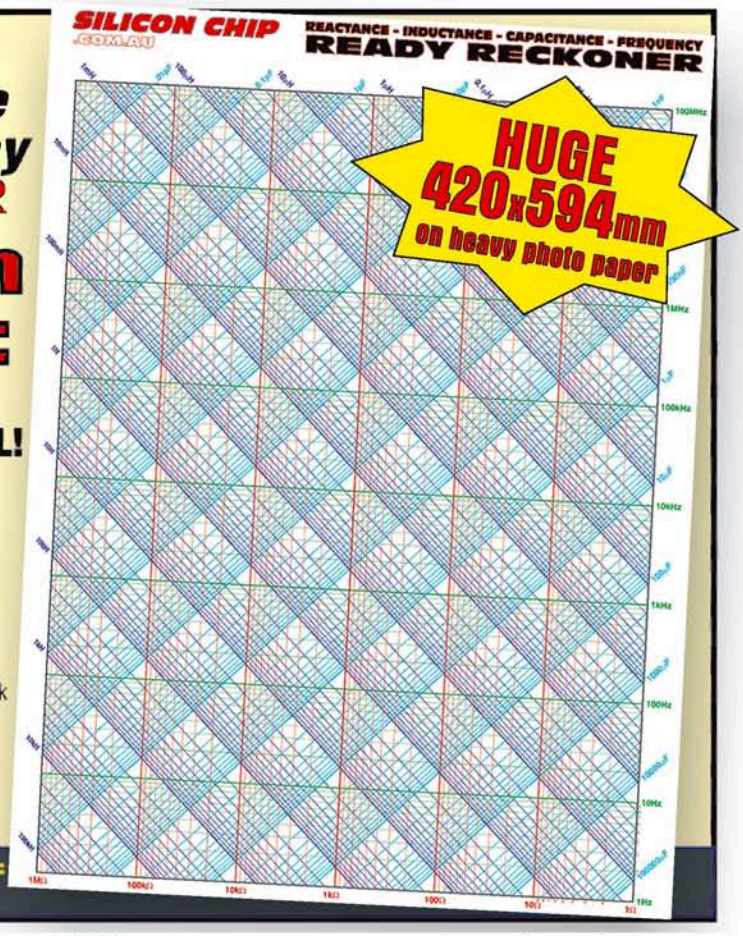

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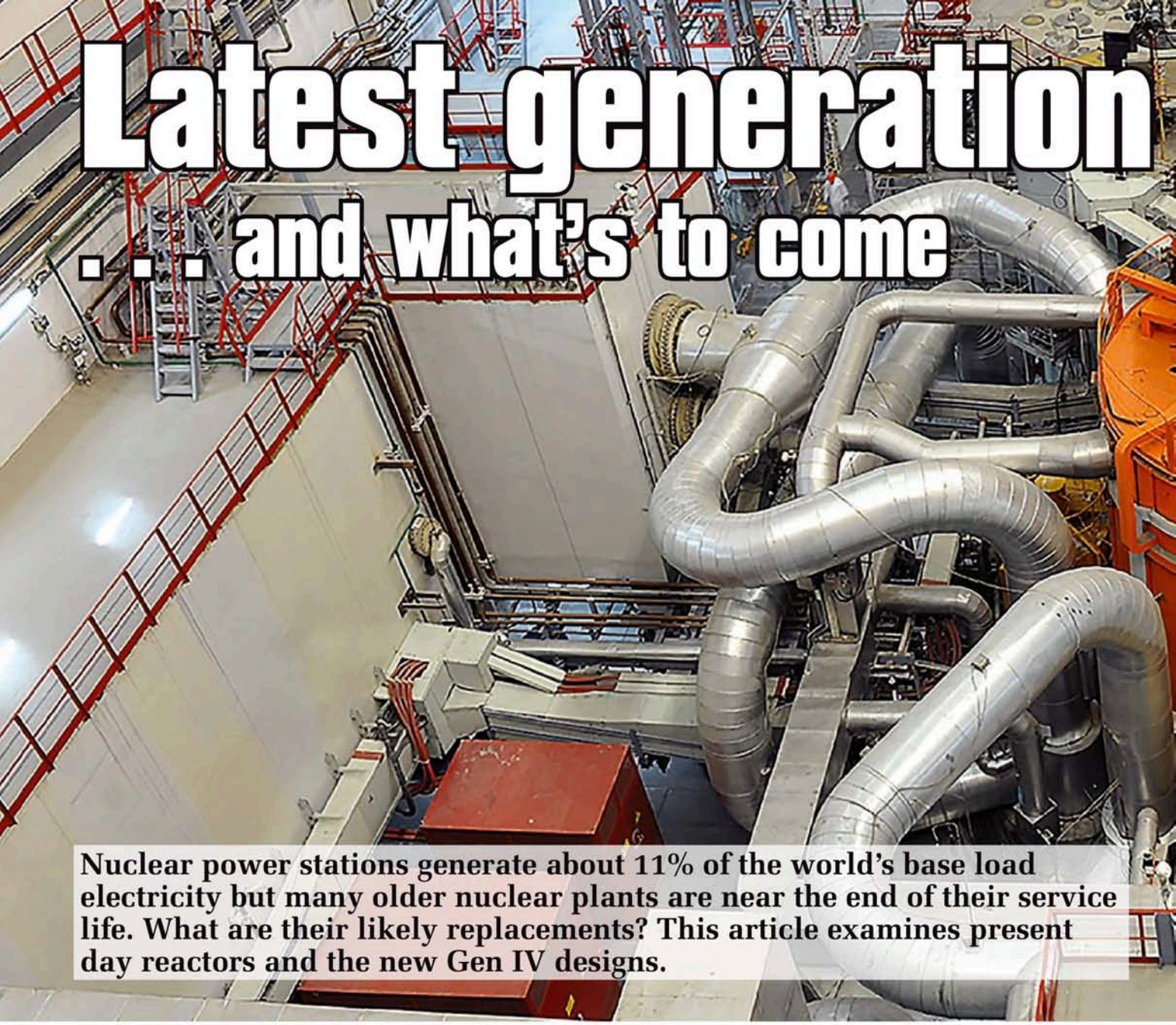
Latest generation . . . and what's to come



Nuclear power stations generate about 11% of the world's base load electricity but many older nuclear plants are near the end of their service life. What are their likely replacements? This article examines present day reactors and the new Gen IV designs.

First, let's look at the most common current design, the pressurised water reactor (PWR) and then we will describe the six Gen IV designs, all selected by the international Gen IV Forum (GIF) committee:

- Sodium Fast Reactor (SFR),
- Lead Fast Reactor (LFR),
- Gas Fast Reactor (GFR),
- Supercritical Water Reactor (SCWR),
- Very High Temperature Reactor (VHTR) and
- Molten Salt Reactor (MSR).

The pressurised water reactor accounts for 65% of the world's ~450 nuclear power plants (NPPs). This wasn't always the case and in the 1950s many countries developed their own designs.

Thus, the Canadians developed the CANDU heavy water moderated reactor that used natural uranium (99.27% U-238, 0.73% U-235). The UK developed the gas-cooled reactors (eg, Magnox and AGRs) which also used natural uranium and are very safe on account of their low power density (with lots of graphite in the core and not a lot of fuel).

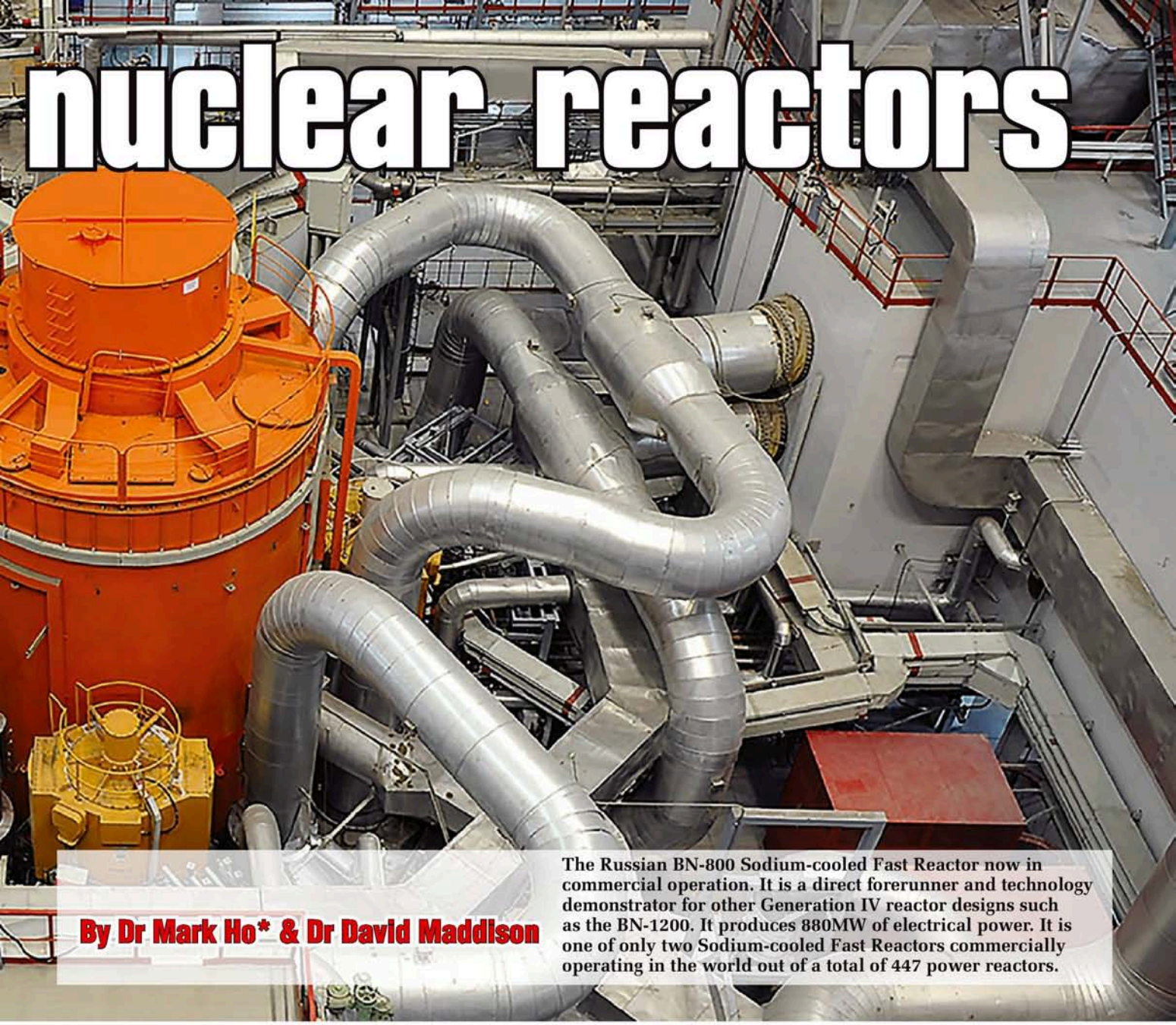
For their part, the Americans developed a compact pressurised water reactor (PWR) that used highly enriched uranium (>20%) to power their naval vessels. From there, they developed land-based PWRs up to 1350MWe (megawatts of electrical power) using low enriched uranium (5%). These have been found to be very economical to operate.

Subsequently, PWRs have been widely deployed in Russia, China, Japan, UK, France and other European Countries, displacing these countries' own designs.

PWRs are very safe on account of their negative thermal reactivity feedback – meaning that the hotter the core gets, the less nuclear reaction takes place in the core. The materials and heat transfer characteristics of PWRs are well known.

Water under pressure is well understood, as are the properties of steel which makes up the reactor pressure vessel (RPV) and the zirconium alloy 'fuel pins' (ie, hollow tubes) that contain the sintered uranium-dioxide fuel pellets.

nuclear reactors



The Russian BN-800 Sodium-cooled Fast Reactor now in commercial operation. It is a direct forerunner and technology demonstrator for other Generation IV reactor designs such as the BN-1200. It produces 880MW of electrical power. It is one of only two Sodium-cooled Fast Reactors commercially operating in the world out of a total of 447 power reactors.

By Dr Mark Ho* & Dr David Maddison

So nuclear regulators have confidence in these designs and PWRs have become the mainstay of the global nuclear fleet.

After some 50 + years of operations, these Generation II PWRs are nearing the end of their service life and are being slowly replaced by Gen III PWRs and BWRs (Boiling Water Reactors which generate steam directly in the reactor core).

Gen III reactors have active and passive safety systems which ensure heat can be removed from the reactor core after shutdown.

Why is this necessary?

In a nuclear reaction, a typical uranium-235 nucleus with 92 protons and 143 neutrons can split after absorbing a neutron, producing two elements of lower mass numbers (fission products), 2-3 neutrons and some energy in the form of gamma radiation.

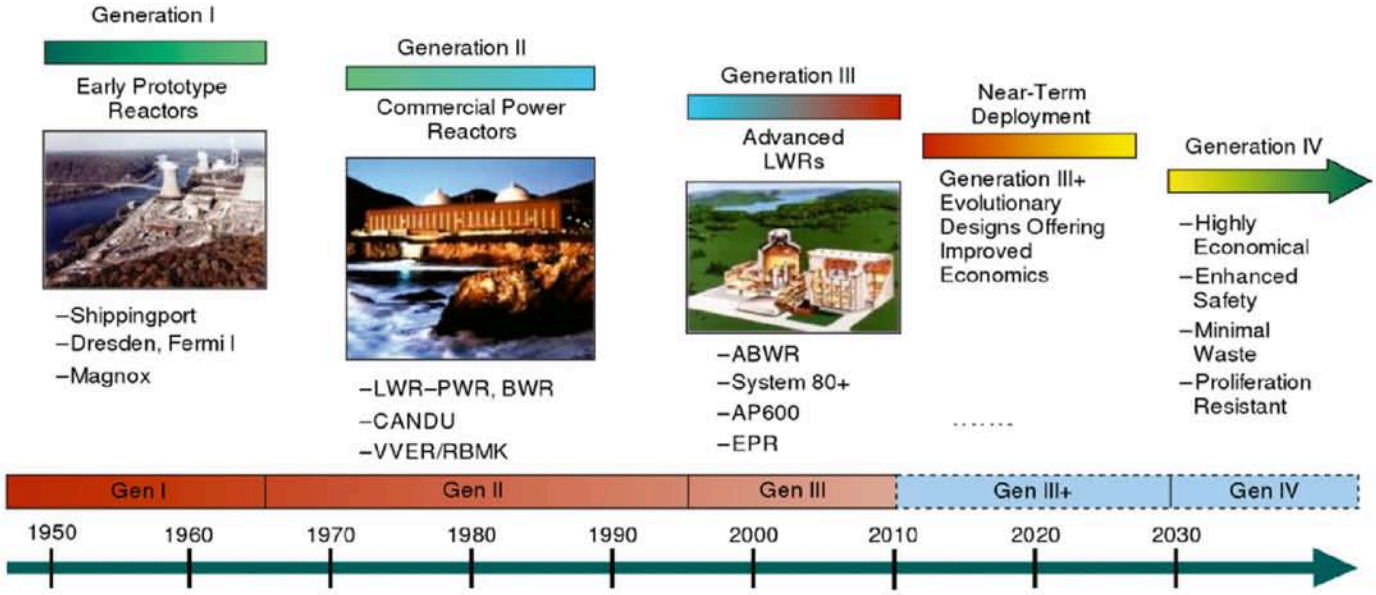
The fission products continue to radioactively decay after shutdown, generating roughly 1.2% of the reactor heat at full power one hour after the control rods are dropped. So for a 3000MW-thermal / 1000MW-electric reactor, the core continues to generate 36MWth (megawatts of thermal output) one hour after shutdown.

This 'decay heat' is removed either by pumps to drive water through the core or as in the case of some Gen III reactors, by natural circulation which does not require pumps or off-site power. New PWRs and BWRs are often built with large water reservoirs that act as a "thermal-sink" for decay heat removal.

By eliminating the need for off-site power, Fukushima-type accidents would be eliminated.

Apart from needing improved safety features, there are other other features which one might have for a nuclear reactor. These include:

(1) to breed nuclear fuel without creating nuclear weapons materials (ie, non-proliferation)
(2) to burn radioactive waste
(3) to burn nuclear fuel more completely
(4) to supply high temperature heat for industrial processes



Timeline showing development of various generations of reactors. Generation IV reactors are intended to be deployable no later than 2030. ***Image credit: US Nuclear Engineering Division***

(5) to operate more economically.

Not surprisingly, these attributes are the expressed goals of the Gen IV forum (GIF) which is a group of 14 nations (now including Australia) working together on the next generation of power reactors.

So let us discuss these desired points.

Fuel breeding and non-proliferation

Currently, PWRs cannot breed enough fuel to be self-sustaining. In fact, readers might be surprised to know PWRs and BWRs do create fuel by exposing the 'fertile' uranium-238 content (95% of the uranium-dioxide) to neutron bombardment. This results in neutron absorption and transmutation into the fuel plutonium-239.

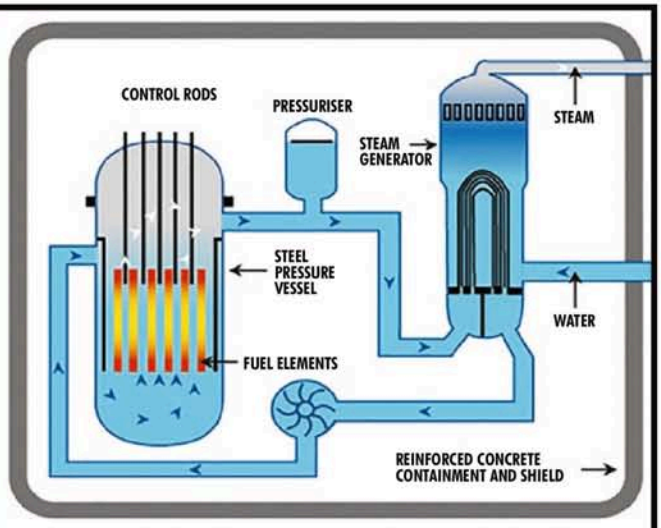
What is more interesting is that about half of the power that comes from a usual 18 month burn-cycle (the duration a fuel bundle is in the core) actually comes from burning plutonium created in the core when exposed to neutrons! Thus the bred plutonium is beneficial as it's essentially 'free power'.

Some people may ask whether "bomb-grade material" is being made in the reactor. The short answer is no, because plutonium 240 is also made along with Pu-239 in the core and the mixture of both makes it unusable as a bomb material.

There is also no easy way to separate Pu-240 from Pu-239 without a dedicated isotopic-separation facility which is difficult to engineer, requires large amounts of power to operate and thus is difficult to hide from satellite surveillance.

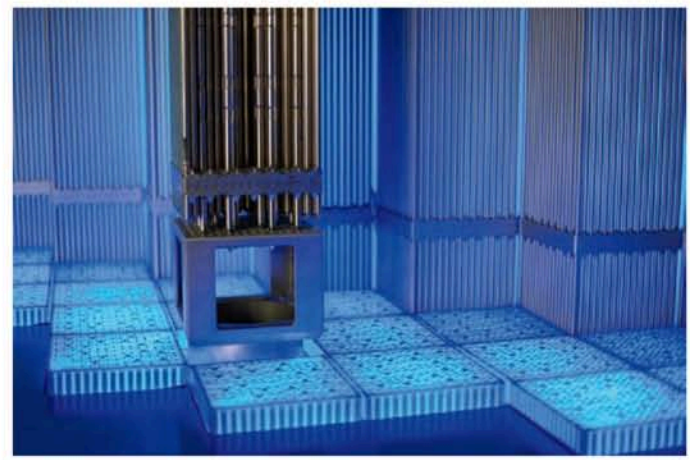
Despite progress made to maximise fuel breeding in PWRs, the maximum PWR conversion ratio (ie, total fuel produced/total fuel burnt) is about 0.6 or 60%.

A self-sustaining fuel cycle would require a conversion ratio above 1.0. To do so would also require a very different type of reactor, one that operates in the 'hard neutron spectrum'.

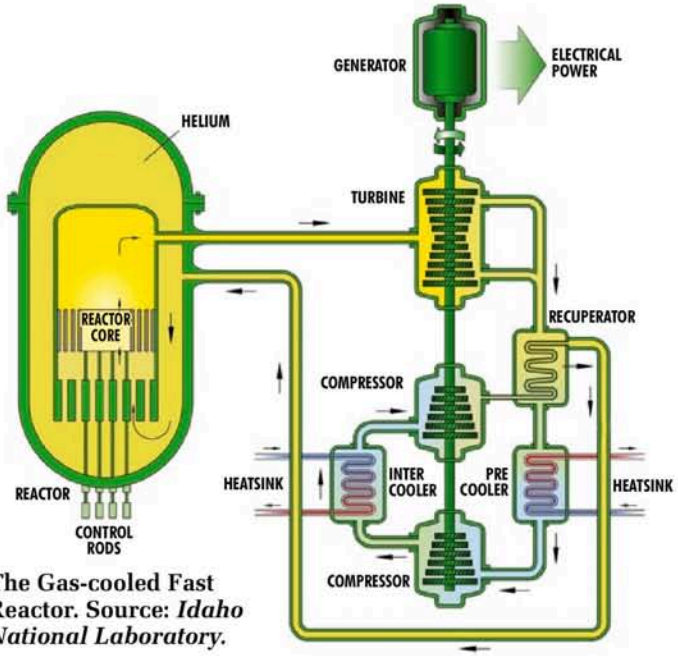


Pressurised Water Reactor

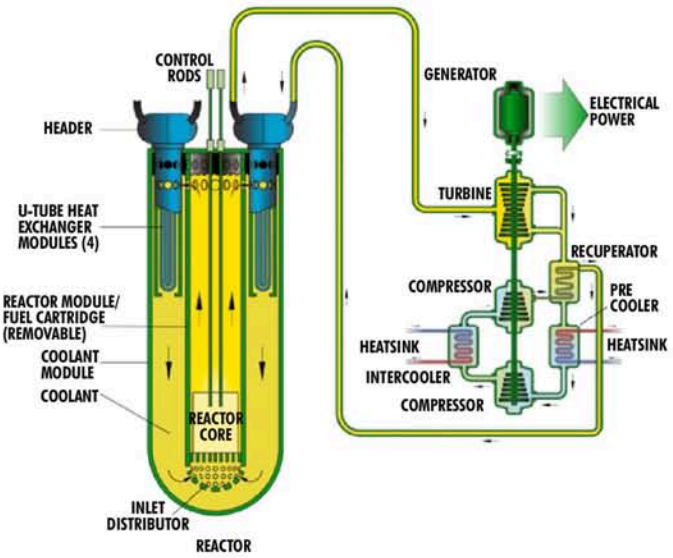
Fuel:	uranium dioxide (4 - 5% enriched)
Fuel Cladding:	Zircaloy (98% zirconium, 2% tin)
Moderator:	light water
Loops :	2 – primary & secondary
Coolant:	light water – light water
Core temperature:	300 – 330°
Operating pressure:	150 atm
Rankine (steam) cycle:	33% efficiency



Nuclear fuel inside a reactor.



The Gas-cooled Fast Reactor. Source: *Idaho National Laboratory.*



Lead-cooled Fast reactor. Note the natural convective pathway for cooling. Source: *Idaho National Laboratory.*

PWRs operate in the thermal neutron spectrum, when neutrons are slowed to the speed of gas molecules at room temperature, about 0.25eV (electron volts). Fast neutron reactors operate in the hard neutron spectrum with neutrons zipping around at 5% the speed of light at ~1MeV.

An example of a much-studied fast reactor is the SFR, the Sodium Fast Reactor.

The conversion ratio for the SFR is theoretically limited to 1.3. Since the conversion value is > 1.0, it's called the "breeding ratio".

The probability of neutron capture for all nuclear fuels are two to three orders of magnitude less in the fast spectrum than in the thermal spectrum. Thus a fast neutron reactor requires a lot more fissile material than a 'thermal reactor' like the PWR. Hence, one can see why thermal-neutron reactors have been in wide usage, as they require less fissile material per reactor to achieve criticality.

For a reactor to be stable, the amount of neutrons produced is balanced by an equal amount of neutrons lost. It is known as achieving criticality in the core when the core reactivity is equal to 1. Less than 1 is sub-critical and more than 1 is super-critical

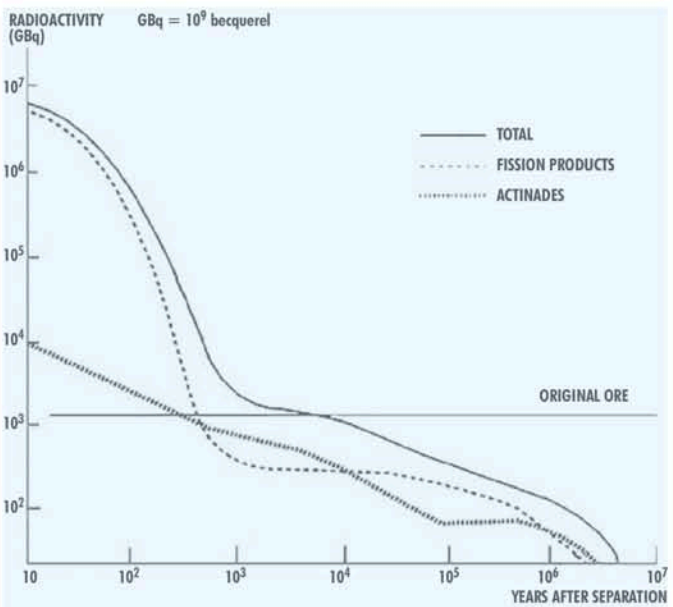
Burning radioactive waste

Radioactive waste created in PWRs and BWRs can be loosely separated into two categories: long-lived and short-lived waste. Short-lived waste comprises fission products with a half-life of about 30 years.

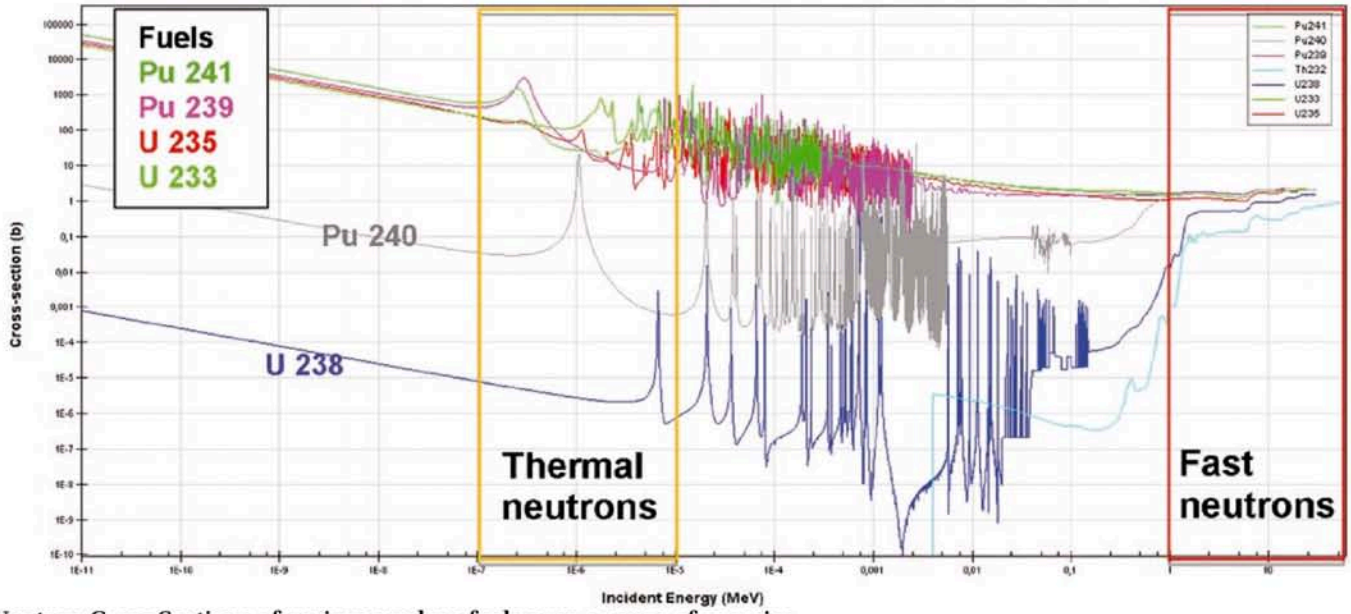
Long-lived waste comprises high mass-number elements created from uranium-238 capturing several neutrons and transmutating into elements such as neptunium, plutonium, americium and curium. These trace elements are known as 'minor actinides' as they are actinides created in small quantities.

What is important to note is that short-lived wastes pretty much fully decay after about 300 years or about 10 successive half-lives, whereas long-lived wastes could last for

Russian hexagonal PWR fuel bundle.



Decay in radioactivity of high-level waste from reprocessing one tonne of spent PWR fuel. The straight line shows the radioactivity of the corresponding amount of uranium ore. Source: *OECD NEA 1996, Radioactive Waste Management in Perspective*.



Neutron Cross Sections of various nuclear fuels over a range of energies.

100,000+ years.

But it is the short-lived waste that is the most radioactive as it's decaying at a much faster rate than the long-lived waste. In reality, radioactive waste is not an insurmountable issue as it is possible to engineer containing structures that are very good at shielding radiation and resistant to corrosion.

When spent fuel is reprocessed and the useful uranium and plutonium content is extracted, the remaining fission products are usually immobilised as glass (vitrified) and this is known as high-level waste which is radioactive for 10,000 years.

For unprocessed fuel assemblies held in hardened, shielded casks, the time it takes for the waste to reach a level of radioactivity no more than in uranium ore is about 120,000 years.

Still, there are some who wish for minor actinides to be destroyed and this can be achieved by "burning" them in a fast neutron reactor. In fact, the Russian BN-600 SFR has been burning excess weapons-grade plutonium since 2012 as per their arms-reduction agreement with the USA. Similarly reprocessed actinide waste can be burnt in the form of mixed-oxide (MOX) fuel.

Better burn-up of nuclear fuels

As stated earlier, PWRs and BWRs use uranium dioxide pellet fuels enclosed in thin-walled zircalloy cladding. These long fuel pins are injected with helium gas and sealed to improve heat conduction. Uranium dioxide is a ceramic with a very high melting point (2865°C!) but is relatively low in thermal conductivity at 2.0 – 2.5W/(m.K) between 900 and 2200°C.

In comparison, stainless steel has a conductivity of 15-18W/(m.K) and Zircalloy 21.5W/(m.K). More important to note is the thermal conductivity in uranium dioxide degrades as fission gasses build up, causing cracks to occur.

Naturally, we want thermal conductivity in the fuel to be as high as possible for effective heat transfer, so fuel must be removed from the reactor before the structure of the pellets starts to degrade substantially. Another factor to consider is fission product (FP) build-up which accumulates as the fuel is burnt.

Fission products parasitically absorb neutrons, affecting the core's neutron economy and thus they restrict the fuel's residence time in the core. For these reasons, fuel bundles usually stay in the core for no longer than two years. The maximum burn-up of reactor fuel is measured as the power created divided by the tons of heavy metal 'burnt'.

For uranium dioxide at 5% enrichment, the burn-up tops out at around 60GW-days/ton of heavy metal (where 'heavy metal' (HM) is a mix of uranium, plutonium and minor actinides). Fast neutron reactors which do not suffer as much for the effect of fission-product build up have been shown to achieve a burn up of up to 200GWd/tHM.

Readers might be surprised to know that PWR-spent fuel

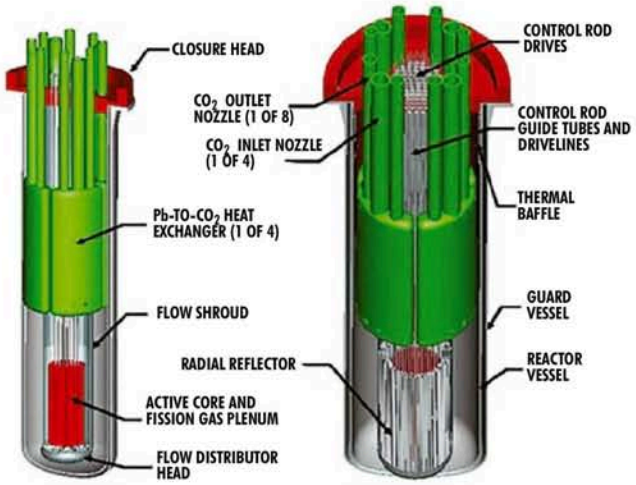
Safety of nuclear power

Despite the claims made often in the popular press, nuclear power is **by far** the safest form of energy production, from mining right through to waste disposal.

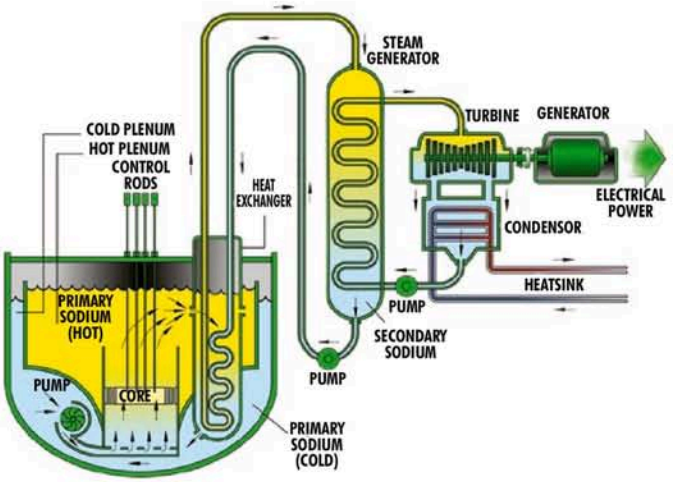
In three significant nuclear incidents, Three Mile Island, Chernobyl and Fukishima, no one died in the first one, 38 died (four in a helicopter accident) in the second one and nobody died in the last one despite 20,000 people dying in the associated tsunami.

The Chernobyl reactor was a simple and cheap design whose purpose, apart from producing electricity, was to generate as a by-product plutonium for nuclear weapons with no regard to safety. Even so, the area around Chernobyl is now a wildlife paradise with many once-endangered species now thriving.

Deaths per terrawatt-hour of electricity produced



SSTAR reactor concept. It is a compact design that has an electrical output of 20MW and when fuel needs to be changed it is removed as a "cassette" by the reactor supplier and replaced with a fresh one. This design is scalable up to an electrical output of 180MW however development seems to have ceased at the moment. A 100MW version would be around 15 metres high and 3 metres in diameter and weigh 500 tonnes.



The GE Hitachi PRISM (Power Reactor Innovative Small Module) reactor is another type of Sodium-cooled Fast Reactor under development. It is a breeder reactor and closes the fuel cycle. It will be produced as 311MW units that are factory assembled. The UK has analysed some scenarios to burn the country's reprocessed spent-fuel using this reactor which could supply the UK's current electrical demand for the next 500 years.

still contains 95% U-238 which can be reprocessed and reused as Mixed Oxide (MOX) fuel in a PWR or any of the other Gen IV reactors.

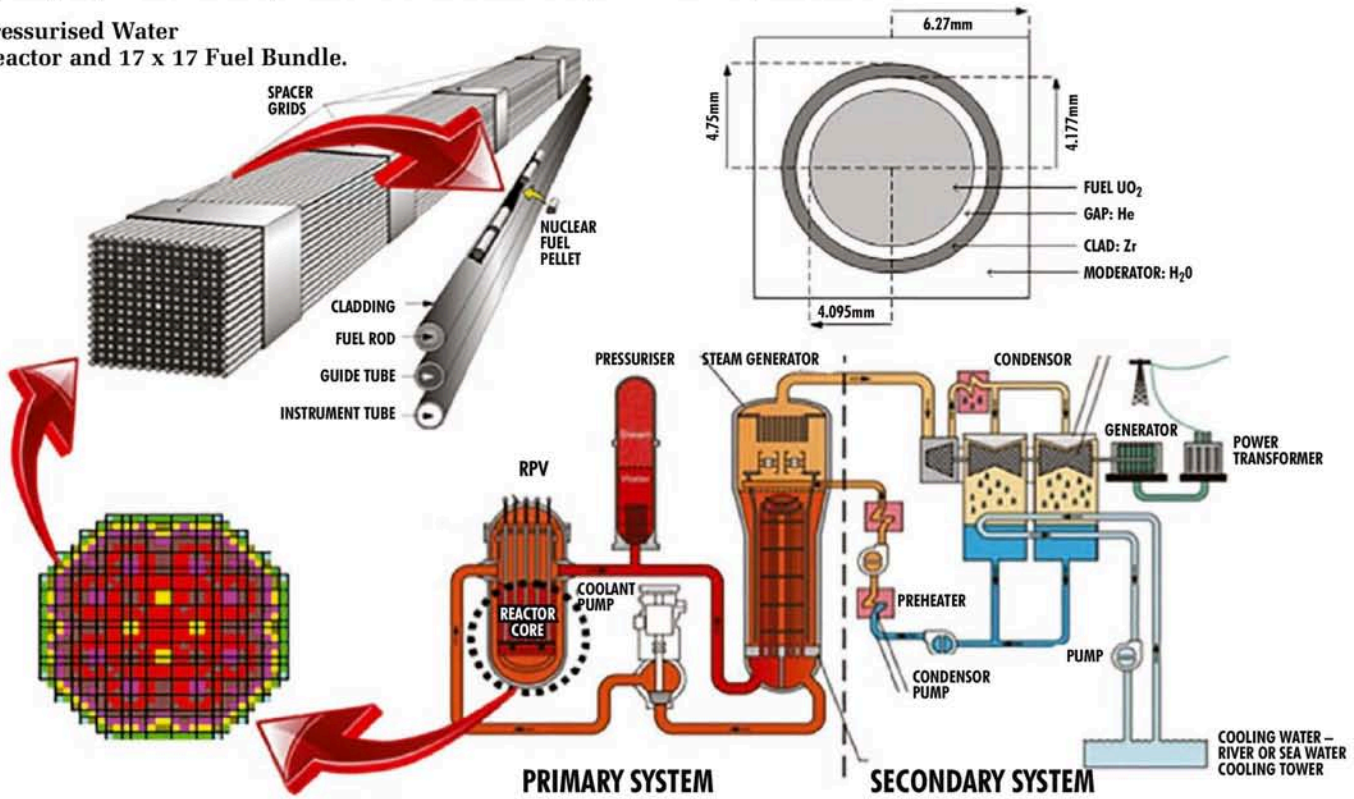
High temperature reactors to supply heat for industrial processes

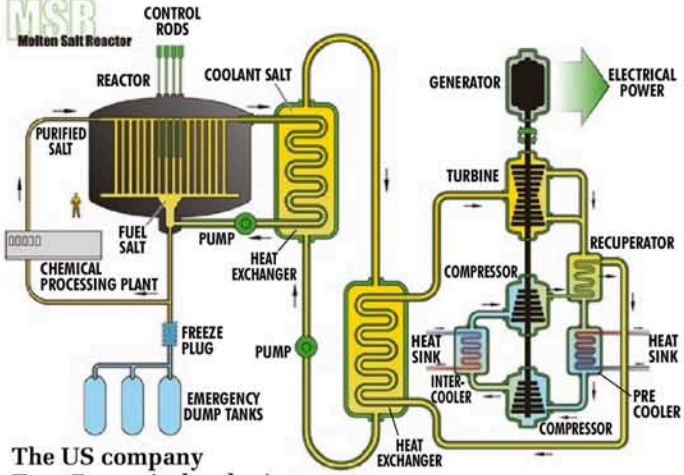
Today's PWRs and BWRs operate at about 300°C which is sufficient to drive a steam turbine at a thermal efficiency of 33% but they are unable to supply the very high temperature heat required for direct-thermal minerals refinement, hydrogen production or synthetic fuel manufacturing.

The limitation for PWRs and BWRs is of water which must remain pressurised to prevent boiling, dry-out and core meltdown. With the exception of the Supercritical Water Reactor, all Gen IV designs circumvent this problem by using more exotic coolants that remain liquid at very high temperatures and without pressurisation.

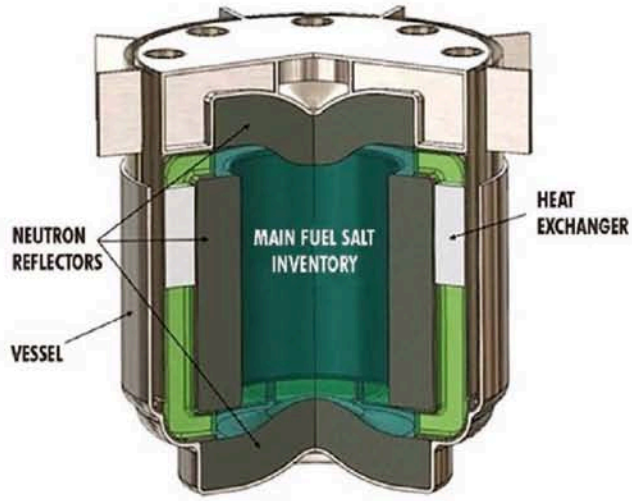
Some of these liquids include sodium (boiling point 892°C), molten salt (bp ~1400°C) and lead (bp 1737°C) which are used in three of the six Gen IV designs. And Very High Temperature Reactors use helium gas instead of a liquid coolant.

Pressurised Water Reactor and 17 x 17 Fuel Bundle.





The US company TerraPower is developing a molten salt reactor using chloride salts rather than the more conventional flouride salts, the Molten Chloride Fast Reactor. It is doing this research alongside its other development project, the Travelling Wave Reactor.



TerraPower's Molten Chloride Fast Reactor.

Economic construction and operation

The Levelised Cost of Electricity (LCOE) is often used to assess the overall cost of a generation system averaged over its lifetime. This takes into account the Capital Cost (build cost), Operating Cost (eg, fuel and maintenance), Grid Connection Cost (eg, grid build-out, stand-by supply) and Financing Cost.

Established nuclear power plants have very low operating costs (as low as 3 US cents/kWh) because the build and financing which currently accounts for 80% of the lifetime costs have usually been paid off.

On the other hand, the LCOE of new nuclear reactors is highly sensitive to the cost of financing (ie, the discount rate usually set at 7%) because nuclear is capital-intensive and much of the investment happens initially during the 5-7 years build phase. Experience in building nuclear reactors also contributes greatly to cost reductions. South Korea has built PWRs continually over the last 30 years and has a LCOE nearly half that of the UK and the United States who are only just restarting their new-build programs.

To counter rising costs, some reactor designers, such as NuScale, are simplifying and miniaturising PWRs in the form of small modular reactors (SMR) that generate 50MWe instead of 1000MWe. (See Silicon Chip, June 2016: "Small Nuclear Reactors" [siliconchip.com.au/Article/9957]).

The intention is to install then in banks of 12 inside a common pool to provide passive heat removal after shutdown. With a bank of 12 50MWe modules, the plant could produce 600MWe, well suited to replace coal plants, for small grid systems or for remote deployment.

The aims are to reduce the build time to three years, improve costs and quality control by building each reactor in a controlled factory environment (instead of an external environment) and to accumulate experience more quickly by building many reactors on an assembly-line, similar to aircraft manufacturing.

To ensure Gen IV designs remain cost-competitive, it will be important to combine the lessons of continual build, design simplification and modular construction with clever design work that incorporates new materials, fuels and exotic coolants.

Reactor safety

Reactor safety involves four main concerns:

(1) ensuring the reactor has a negative thermal reactivity characteristic so that an increase in core temperature decreases fission activity;

(2) maintaining structural integrity in the fuel, cladding and primary loop containing the coolant that circulates through the core;

(3) avoiding total coolant phase-change (and thus loss of flow) in the core in the event of a reactor power excursion or reactivity spike and

(4) the ability to remove decay heat after shut-down. PWRs have by-and-large demonstrated these characteristics. Only when there is insufficient decay heat removal does the question of boiling, structural integrity and fission product release come into play.

To improve the intrinsic safety of future reactors, three Gen IV designs: the Sodium Fast Reactor, Lead Fast Reactor and Molten Salt Reactor (SFR, LFR, MSR) use unpressurised, high boiling-point liquid coolants that can ensure uninterrupted passive decay heat removal.

Liquid metal coolants such as sodium and lead are also very good conductors of heat, so the task of decay heat removal is easily achieved. The Very High Temperature Reactor and Gas Fast Reactor (VHTR, GFR) circumvent the coolant phase change problem entirely by using helium gas as the coolant.

For high temperature reactors such as SFRs, LFRs, VHTRs and MSRs, passive decay heat removal using air instead of water is achievable because of the large temperature difference between the core and the ambient air temperature.

Now let us take a look at the Gen IV designs, focusing on the sodium fast reactor and molten salt reactor.

Sodium Fast Reactors

The end of the Second World War ushered in the Atomic Age which promised a seemingly inexhaustible energy supply. But there was concern amongst scientists that the world's uranium resources were limited and could be quickly exhausted. Thus, work started on "breeder reactors" which could create more fuel than was burnt.

In the course of testing the neutron cross-section of different materials, it was found that sodium was one of the most neutron-transparent, being six times less neutron absorbing than lead. This made sodium an excellent candidate as a reactor coolant to maximise the reactor core's neutron flux.

More neutrons in the core meant the possibility of using excess neutrons to transmute fertile uranium-238 into plutonium-239 fuel or burning neutron-parasitic actinide-waste. Another feature of sodium is that it is only lightly moderating which means a sodium-cooled reactor could operate in a fast spectrum and directly burn uranium-238, something that thermal-neutron spectrum reactors cannot do.

By calculations, a sodium fast reactor could theoretically attain a breeding ratio of 1.3, meaning that 30% more fuel could be produced than is used. In comparison, a lead fast reactor has a theoretical breeding ratio of 1.0 (making it an "iso-breeder") and a PWR has a conversion ratio of 0.6 (making it a "converter" as noted earlier).

By utilising SFRs, it has been calculated that uranium resources can extend the life of economically recoverable reserves by at least 60 times. Before the Gen IV forum started, there was already much co-operation between the US, Russia, France and the UK on SFRs.

Sharing SFR research in the interest of reactor safety was deemed more important than the possibility of future commercial conflicts of interest. So information on materials neutron cross-section measurements, zero-power critical assembly studies, SRF core layouts optimisation studies and safety analysis research were shared. As a result, the SFR core layouts of most countries ended up being quite similar.

SFR fuel

SFRs are similar to PWRs in their use of uranium dioxide and plutonium dioxide fuels. In the future uranium nitride, which can carry a higher uranium loading per unit volume and metallic fuels, which have better heat conductivity, could become a possibility.

Plutonium has a larger neutron cross section than uranium for neutrons above 1MeV. Thus, a Fast Neutron Reactors is actually optimised to burn plutonium.

Also, the number of neutrons produced per plutonium-239 fission is 25% more than from uranium-235 and neutrons produced from Pu-239 are more energetic, thus are better at maintaining the fission process. As mentioned earlier, U-238 under neutron bombardment transmutes into Pu-239 and Pu-241 that can be burnt as fuel and some U-238 can be directly burnt by 1MeV neutrons.

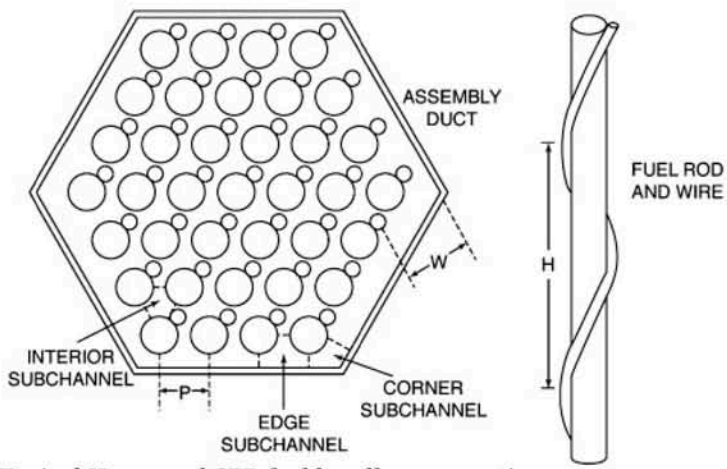
SFR design

A typical SFR fuel bundle is shown opposite. The fuel pins which contain uranium dioxide pellets are packed into a tight hexagonal arrangement to maximise the core's neutron flux. Stainless steel instead of Zircalloy is used for the fuel rods as stainless steel is transparent to fast neutrons, not-corroded by sodium and relatively inexpensive to fabricate.

The fuel rod wires that curl around the fuel pin promote flow, mixing and prevent flow dead-spots from forming. Finally the hexagonal fuel bundle is surrounded by a hexagonal shroud to prevent the possibility of large cross flows which would result in fuel bundle vibrations. To maintain a high neutron flux, SFR cores are typically smaller than PWRs (eg, The Dourneay FR 65MWth was the size of a rubbish bin) but because of the smaller neutron cross sections of 1MeV neutrons, the fissile loading of SFRs are typically three times that of PWRs.

A higher core power density necessitates a superior form of coolant which is why liquid metal is used. Passive reactor control is maintained by a strong negative temperature coefficient which for fast reactors is dependent on the Doppler Broadening phenomenon. When nuclear fuel is heated, the resonance energies for capturing neutrons broaden, resulting in neutron absorption instead of fission. (ie, the fuel becomes self-shielding from neutrons).

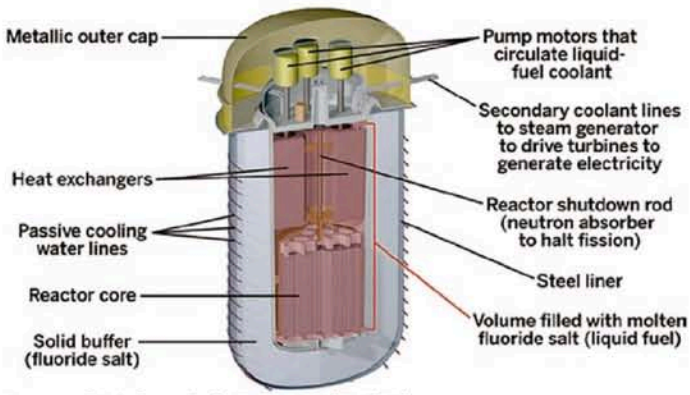
Since sodium is very reactive to water, most SFRs use an 'integral design' to prevent coolant leakage. In an in-



Typical Hexagonal SFR fuel bundle cross section.

Specific advantages of Generation IV reactors

- Greater fuel efficiency than current Generation III+ reactors with 100 to 300 times more energy output for a given amount of fuel. There will be less useful fuel left over in waste.
- In some reactor designs, existing nuclear waste can be consumed, extending the effective nuclear fuel supply by orders of magnitude. For example, it has been estimated that if the existing nuclear waste of the United States was dug up and used in new reactor designs it could keep the entire US supplied with nuclear electricity for 70 years. This concept also closes the nuclear fuel cycle, meaning the waste is reprocessed as opposed to the "once through" or "open fuel cycle" in which waste is buried rather than reprocessed.
- Waste products that are hazardous for only centuries instead of thousands of years. From current engineering experience we know that structures such as buildings can easily last hundreds of years, even those built with centuries old technology so underground containment structures should pose no problem.
- Many different types of nuclear fuels can be used with different encapsulation methods such as in ceramics or no encapsulation.
- Reactor designs are designed to be intrinsically safe with no external emergency shut down systems or power required in the event of an emergency and (depending on design) low pressure reactor operation. A Fukushima type event where external power failed would not lead to reactor failure.



Integral Molten Salt Reactor (IMSR).

tegral configuration, the core sits in a large pool of liquid sodium with a cover gas – typically argon.

Having the total primary sodium coolant held inside the thick walled reactor vessel minimises the risk of sodium leakage. For the BN-800 reactor heat removal is accomplished by three independent coolant loops supplying power to a common turbine.

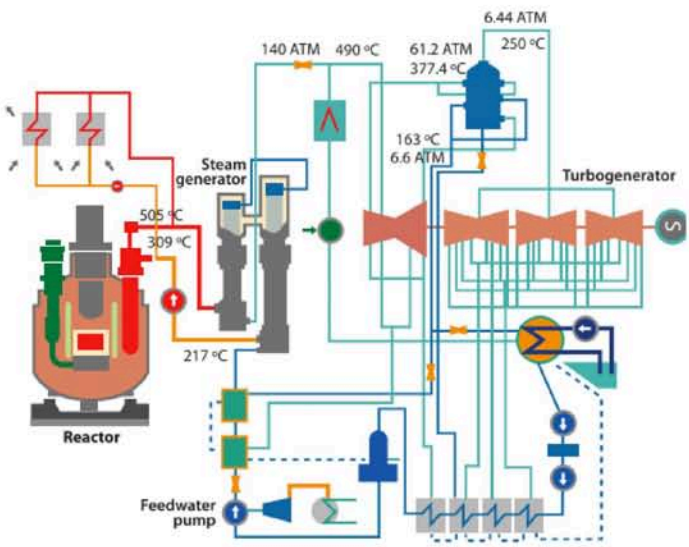
Each loop is comprised of a primary, secondary and tertiary circuit which transfers power to the turbines but also isolates the very radioactive primary sodium coolant from the water-based tertiary coolant. The SFR core operates at a higher temperature than PWRs with an exit temperature of 547°C which allows it to drive a superheated steam cycle at ~40% efficiency.

Future of SFRs

In total, 20 SFRs have operated since the 1950s, accumulating a total of 400+ SFR reactor years of experience. The list of past SFR prototypes includes:

(1) Experimental Breeder Reactors 1 & 2 (USA)
(2) BOR / BN series (Russia)
(3) Phénix and Superphénix (France)
(4) Dounreay FR and PFR (UK)
(5) Monju (Japan) and
(6) CEFR (China).

After a flurry of initial research, most SFR prototypes



BN-800 fuel flow diagram. Three consecutive coolant circuits prevent radioactivity from penetrating into the steam generators.

have permanently shut down after uranium reserves were found to be much more plentiful than initially thought and PWRs & BWRs were optimised to run economically. The exception is in Russia who has operated the BN-600 (600MWe) SFR since the 1980s and have recently commissioned their BN-800 reactor.

There are plans to build an even larger BN-1200 reactor which will further simplify the core design and test new fuels and materials in the quest to close the nuclear fuel cycle (ie, fully consume all radioactive waste generated).

In terms of cost, SFRs are currently more expensive to run than PWRs. It was reported that BN-800 capital costs were 20% more than a Russian VVER-1200 (Russian PWR) and BN-800 operational costs were 15% more than a VVER.

Still, work continues on SFRs in some countries such as France who are planning to build the next generation SFR called "Astrid" and have studied scenarios to replace half of the current PWR fleet with SFRs.

The UK Department of Energy and Climate Change had also studied scenarios of eventually phasing out PWRs with SFRs but has opted to focus on PWRs and BWRs in its new-build program. China, which is currently building most of the world's PWRs, plans to build its own BN-800 reactor with Russian assistance.

In the West, multiple SFR designs are on the drawing board such as the GE Hitachi PRISM reactor and the TerraPower Travelling Wave reactor (TWR). TerraPower recently entered into partnership with China National Nuclear Corporation (CNNC) to further develop the Travelling Wave reactor. The intended purpose of the TWR is to burn spent fuel generated in PWRs using less nuclear fuel and producing less nuclear waste than today's PWRs.

Molten Salt Reactors

Molten salt reactors use fluoride or chloride salts as coolant and can be designed to burn either solid fuels (SF) or liquid fuels (LF).

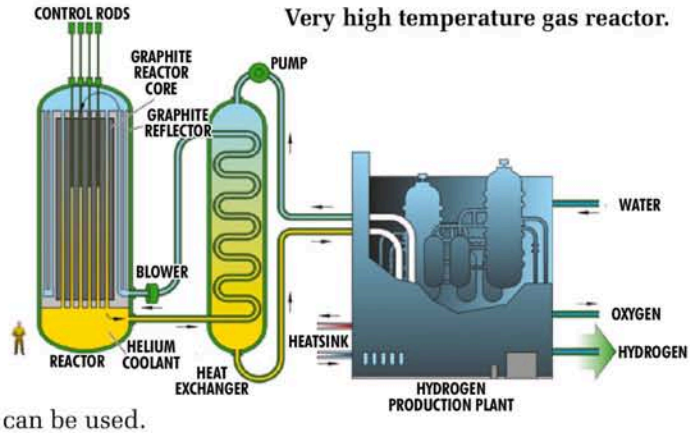
The salt is not dissolved in water; the salt in molten form is the coolant. The choice between a chloride or fluoride salt depends on the desired neutron spectrum. Lithium-beryllium fluoride (FLiBe) works as a thermal spectrum salt on account of the low mass numbers of lithium and beryllium.

Chloride salts paired with heavier elements are much less moderating and good at maintaining a fast neutron-spectrum. All salts have excellent heat transfer characteristics. For example FLiBe salt has the same volumetric heat capacity as water but remains a liquid up to 1400°C without pressurisation.

This is due to the FLiBe salts having a very low vapour pressure (ie, rate of evaporation). Other attractive aspects of the salt include a low neutron absorption cross section, resistance to radiation damage on account of their ionic bonds, being non-reactive to air or water and visually transparent.

MSRs possess a substantial safety margin between the reactor's operational temperature and the salt's much higher boiling point, as boiling could lead to a loss-of-flow accident in the core. Added to this, since pressurisation is not required, the reactor pressure vessel (RPV) can be designed to have a thinner wall compared to the 20cm thickness of a PWR RPV.

Due to the MSR's high core temperature, a Brayton-cycle gas turbine operating at a high thermal efficiency of 45%



Very high temperature gas reactor.

can be used.

Solid Fuel MSRs

Current SF-MSR designs are salt-cooled, graphite-moderated reactors that use TRISO (Tri-structural-isotropic) fuel that was developed during earlier research into High Temperature Gas Reactors (HTGRs). TRISO fuel is composed of thousands of 0.5 mm diameter uranium dioxide kernels wrapped in layers of carbon and silicon carbide that trap solid and gaseous fission products without degrading the fuel's thermal conductivity.

A sphere of ten thousand TRISO particles is surrounded by layer of graphite, making a 6cm diameter ball (known as pebble fuel). Alternatively, TRISO fuel can be made into large prismatic blocks of graphite with TRISO particles dispersed on the surfaces that interface with the salt coolant.

TRISO fuel is more accident-tolerant than standard PWR fuel and has been tested to withstand temperatures up to 1800˚C without fission product release but the layers of silicon carbide and carbon also make the fuel difficult to reprocess and reuse so this is counter to the goal of closing the fuel cycle.

One may think of the SF-MSR design as being very similar to a HTGR. Both use TRISO pebble fuel and operate in a thermal neutron spectrum but the helium coolant in a HTGR is swapped out for the FLiBe salt. The operation of SF-MSRs is similar to PWRs as both need periodic refuelling but fuel burn-up is enhanced due to TRISO fuel's superior thermal-performance.

One advantage of the SF-MSR is that it is more compact than a HTGR due to the salt's higher volumetric heat capacity. On the other hand, FLiBe coolant is more expensive to manufacture than helium. Currently, the Shanghai Institute of Applied Physics (SINAP), Oak Ridge National Laboratory (ORNL) and Kairos Energy based in California are continuing research on SF-MSR designs.

Liquid Fuel Thermal MSRs

Liquid fuel, molten salt reactors use fuel (233UF4, 235UF4 or 239PuF4) that is directly dissolved into the primary coolant itself. Having the fuel dissolved provides some advantages for thermal-spectrum LF MSRs: 135Xenon – a highly neutron parasitic fission product – can be removed as a gas during operation and refuelling can occur while the reactor is running.

The ability to constantly remove fission products means a much higher rate of burn-up can be achieved (>50%) and also means less decay heat to contend with after the reactor is shut down. The fact that both the fuel and the beryllium moderator are in a liquid form results in them readily expanding at high temperatures, giving the MSR a highly negative reactivity thermal coefficient that prevents a runaway chain reaction.

However, having a fuel in solution also means the primary coolant salt becomes highly radioactive, complicating maintenance procedures and the chemistry of the salt must be monitored closely to minimise corrosion. Another advantage of the liquid fuel molten salt design is that it allows the breeding of 233U from 232Th in the thermal/epithermal neutron spectrum instead of using a fast-spectrum.

Neutron capture by thorium-232 results in beta decay (one of the neutrons in the thorium nucleus expels an electron to become a proton) thus transmutating into rotactinium-233 which further beta decays into uranium-233. The U-233 could then be used as an MSR fuel. The thorium fuel cycle holds promise and studies have shown that a breeding ratio of 1.06 to 1.14 is possible for thermal and epithermal spectrum MSRs.

Despite the potential for breeding fuel, current efforts are focused on simply bringing the LF-MSR to the commercial market – one which satisfies the nuclear regulator's stringent demands for safety. Various LF-MSR start-up companies are approaching the problem from different angles.

Terrestrial Energy's (Canada) "Integral Molten Salt Reactor" (IMSR) uses low enriched (5%) uranium (ie, denatured uranium) dissolved in the salt coolant. The reactor vessel is designed to be swapped out every seven years to address possible issues with salt corrosion.

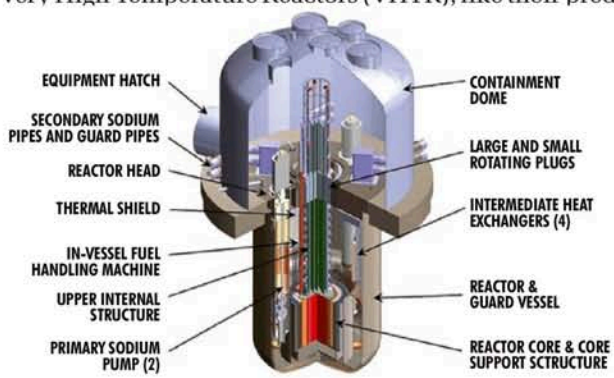
Another company, ThorCon, has a similar design, using a FLiBe salt and graphite moderator but fitted on a ship. Transatomic has a design using lithium-fluoride salt instead of FLiBe and zirconium hydroxide instead of graphite as the moderator with a view to burn radioactive waste.

The Shanghai Institute of Applied Physics is also pursuing a LF-MSR design and has worked with Oak Ridge National Labs and with ANSTO on corrosion resistant materials development. SINAP has secured $3.3 billion USD to build a 10MWth thermal-spectrum LF-MSR prototype by 2020.

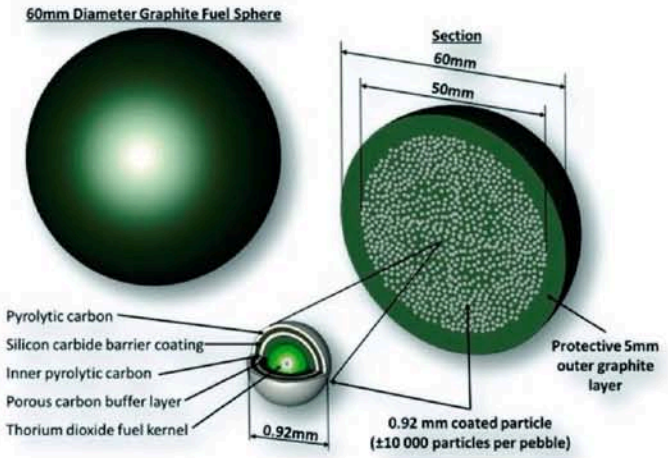
Fast spectrum, chloride-salt designs are being pursued by the European SAMOFAR (Safety Assessment of the Molten Salt Fast Reactor) consortium, Elysium Inc. (USA) and Terrapower's MCFR (Molten Chloride Fast Reactor) which aims to burn the 700,000 tonnes of uranium held in spent fuel from PWR and BWR operations in the USA.

VHTRs, GFRs, SCWRs & LFRs

Very High Temperature Reactors (VHTR), like their prede-



The travelling wave reactor (TerraPower).



Fuel pellets for Terrapower Molten Chloride Fast Reactor

cessor the HTGRs, are graphite-moderated, helium-cooled reactors with a once-through fuel cycle (ie, the fuel is not reprocessed) using TRISO fuel. VHTRs have a target operational temperature of 900°C whereas HTGRs' core outlet temperature is about 700°C.

The higher temperature of 900°C would enable hydrogen production or the delivery of heat for industrial processes. Difficulties in realising a VHTR design are mainly due to the limitations of material performance as the rate of material corrosion increases linearly with temperature. Thus materials research is continuing to enable the VHTR concept.

The USA, Russia, South Africa, Japan and the UK have all built experimental HTGRs. China is close to completing two HTR-PM (High-Temperature Reactor – Pebble Module) prototypes which will deliver superheated steam to a common turbine generating 210MWe.

Limiting the thermal output of each HTR-PM unit to below 300MWth ensures the maximum fuel temperature limit of 1600°C will not be compromised after reactor shutdown, thus guaranteeing the reactor's inherent safety. It is envisaged new HTR-PM units will replace current coal plants which drive the same superheated steam cycle and so quickly reduce China's pollution problems.

Gas Fast Reactors (GFRs) can be thought of as an extension of VHTR technology but with a higher fissile loading (on account of the fast spectrum) and without the presence of moderating graphite. It is a challenging design as the removal of the graphite severely reduces the core's thermal inertia (ie, the ability of the core material to 'suck up' the decay heat).

Progress on this design has been slow and depends on the outcome of VHTR research.

The Supercritical Water Reactor (SCWR) could be thought of as a Boiling Water Reactor with the primary loop directly driving a steam turbine.

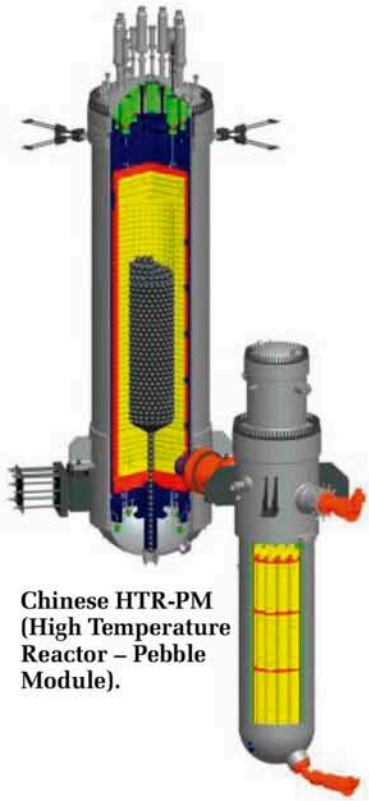
The water coolant is heated beyond 375°C and 22.1MPa in a super-critical state whereby the total liquid inventory behaves like steam and the transitional dynamics of boiling can be avoided.

This design is focused mainly on improving the efficiency of the thermal cycle but faces the challenges of increased thermal stress on reactor components, accelerated corrosion rates at elevated temperatures and a reduced water inventory in the primary loop which normally serves as a buffer for sharp changes in reactor power.

(For more on supercritical steam see SILICON CHIP, December 2015 – siliconchip.com.au/Article/9634).

The last Gen IV reactor design is the Lead Fast Reactor. Both the US and Russia have studied reactor concepts using a lead coolant but only Russia has fielded the LFR in its naval vessel, most notably in the Alfa-class attack-submarine (see below).

Since fast reactors operate with a compact core to maximise the neutron flux, the lead-bismuth cooled OK-550 fast reactor with an output of 60MWe could fit inside a small cross-sectional hull and propel the submarine up to 41 knots (76km/h!)



Chinese HTR-PM (High Temperature Reactor – Pebble Module).

These submarines have all been decommissioned but plans for the new BREST-300 LFR was recently granted approval for construction in Seversk, Russia and will serve as the demonstrator unit before the larger BREST-1200 unit is built.

This concludes our brief run-down of all the six Gen IV designs. All nuclear power reactors must extract large amounts of power from the small volume of the core. This necessitates both the fuel and the coolant to be in close contact with one another to maximise reactor heat transfer.

Added to this, neutrons must be used sparingly via the careful selection of component material so that excess neutrons can be used to either bred fuel or burn radioactive waste.

In the end, the whole reactor system must be contained by a durable and inexpensive material, resistant to corrosion and radiation damage. SC

***Dr Mark Ho is the current president of the Australian Nuclear Association.** www.nuclearaustralia.org.au/

The Russian Alfa-class submarine which used a lead-bismuth fast reactor. It could run at up to 41 knots.

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Triac-based for *ultra-smooth* control!

BY JOHN CLARKE

Full-Wave, 10A Universal

This relatively simple but highly effective Triac-based circuit gives smooth, full range speed control for electric drills, lawn edgers, circular saws, routers or any other appliance with universal motors (ie, brush-type), rated up to 10A.

Most SCR or Triac-based speed controllers usually have very poor low-speed control and won't let the motor reach full speed. This speed limitation comes about because these circuits can only switch on every second half-wave of the 230VAC mains voltage. This means that they can only feed a maximum voltage of about 160VAC to the motor.

These limitations are demonstrated in the waveforms shown in Scope1 and Scope2, which come from the Half-Wave Speed Controller published in February 2009.

Up till now it has been very difficult to design a Triac-based circuit which would give smooth control over a wide range of speeds.

Nor was it is easy to provide good speed regulation which means that the motor speed is less likely to vary if the loading changes.

But our new Full Wave Universal Motor Speed Controller provides much improved speed control because it not only uses a microcontroller to provide more precise phase control of the Triac but it also employs current feedback.

This is not our first full range speed control for universal motors. Our last design was featured in the February and March 2014 issues. See www.siliconchip.com.au/Series/195

This had a complex circuit that rectified the 230VAC mains and used a rugged IGBT (insulated gate bipolar transistor) to rapidly switch the pulsating DC waveform at 980Hz.

At low speeds, very narrow pulses are applied to the motor while at full speed the IGBT is continually on. This technique is referred to as pulse width modulation (PWM).

That design is still valid but due to its complexity, it also meant that it was (and still is), large and expensive.

Our new Triac-based design

Features

- Full wave motor control
- Full speed range
- 220VAC to 250VAC 50Hz/60Hz
- For "universal" motors (ie, series motors with brushes)
- 10A 230VAC or similar nameplate rating
- Soft start

Motor Speed Controller

also offers impressive performance but it is less complex and less costly. The Triac is phase-controlled and works similarly to a leading edge light dimmer (more on phase control later).

The 600V 40A Triac is also arguably more rugged than the IGBT used in the 2014 design. For an explanation of leading and trailing edge dimmer operation, see our article in the July 2017 issue (www.siliconchip.com.au/Article/10712)

By the way, our new circuit offers much better speed control than our Mk2 phase controller from February 2009 which used the same BTA41 Triac. See www.siliconchip.com.au/Article/1339

Soft start

A particularly attractive feature of this new design is "soft start". This means that regardless of speed setting, the motor speed will smoothly build up to the setting and thereby avoid any sudden kicks – an all-too-common reason for users presenting at hospital casualty rooms!

The new Speed Controller can be used with a 220 to 250VAC mains supply, at 50Hz or 60Hz. This means that it can be used in any country that has a 220VAC or above. However, it is not directly suitable for use with a 110VAC mains supply; that would required some component changes.

Why do you need speed control?

Most power tools will do a better job if they have a speed control. For example, electric drills should be slowed down when using larger drill bits. This is particularly the case when drilling sheet metal; using too fast a speed will result in a triangular hole.

Similarly, it is useful to be able to slow down routers, jigsaws and even circular saws when cutting some materials, particularly plastics, as many plastics will melt rather than be cut if the speed is too high.

The same comments apply to sanding and polishing tools and even electric lawn trimmers, where they are less likely to snap their lines when slowed down.

Even if you do not want a reduced motor speed, the soft start feature of this Speed Control is handy when using large power tools such as circular saws and routers which can otherwise give a substantial kick if started at full voltage. (Some modern power tools, such as electric chainsaws, have this feature built-in).

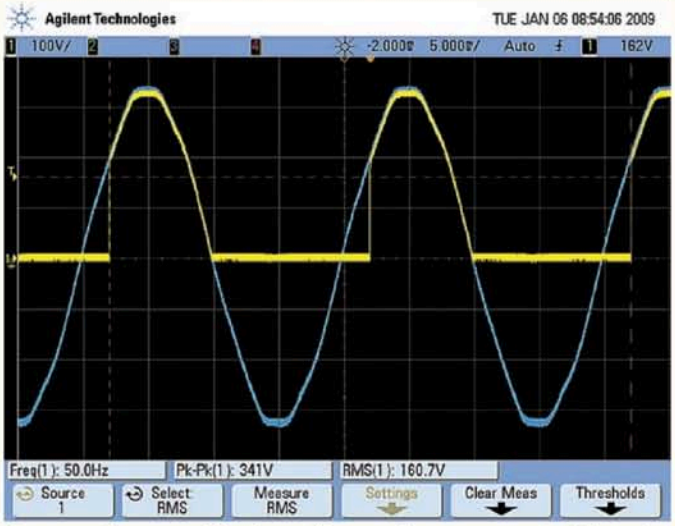
Phase control

Before we continue, we should explain what we mean by phase control that is used in this new design.

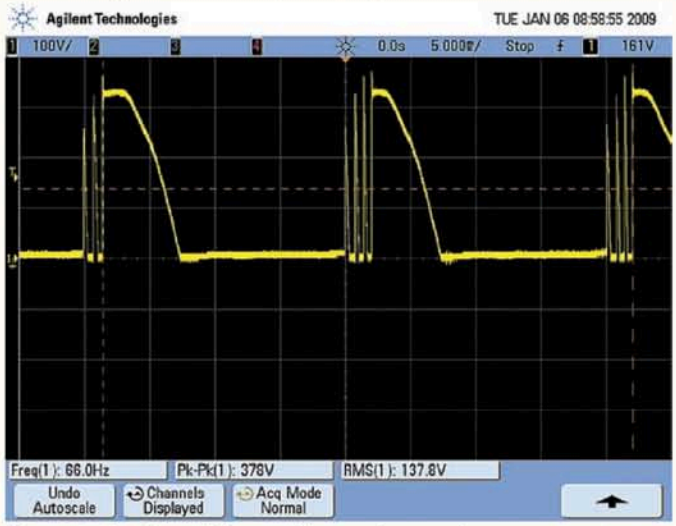
As you know, the mains AC voltage is a sinewave. It starts at zero, rises to a peak, falls back to zero, then does the same thing with the opposite polarity. This repeats 50 times each second for 50Hz mains and 60 times per second for 60Hz mains.

We vary the speed of a motor by varying the time during each half cycle when power is applied: feed power very early in the cycle and it runs fast; delay applying power until much later in the cycle and it runs slowly.

These half-wave control waveforms are taken from our February 2009 Drill Speed Controller, for comparison with the new one . . .



Scope1: the controller is set for maximum output with resistive load. The yellow waveform is essentially a half-wave rectified sinewave with a value of 161V RMS (70% of the blue 230V mains waveform) and a peak value of 341V.

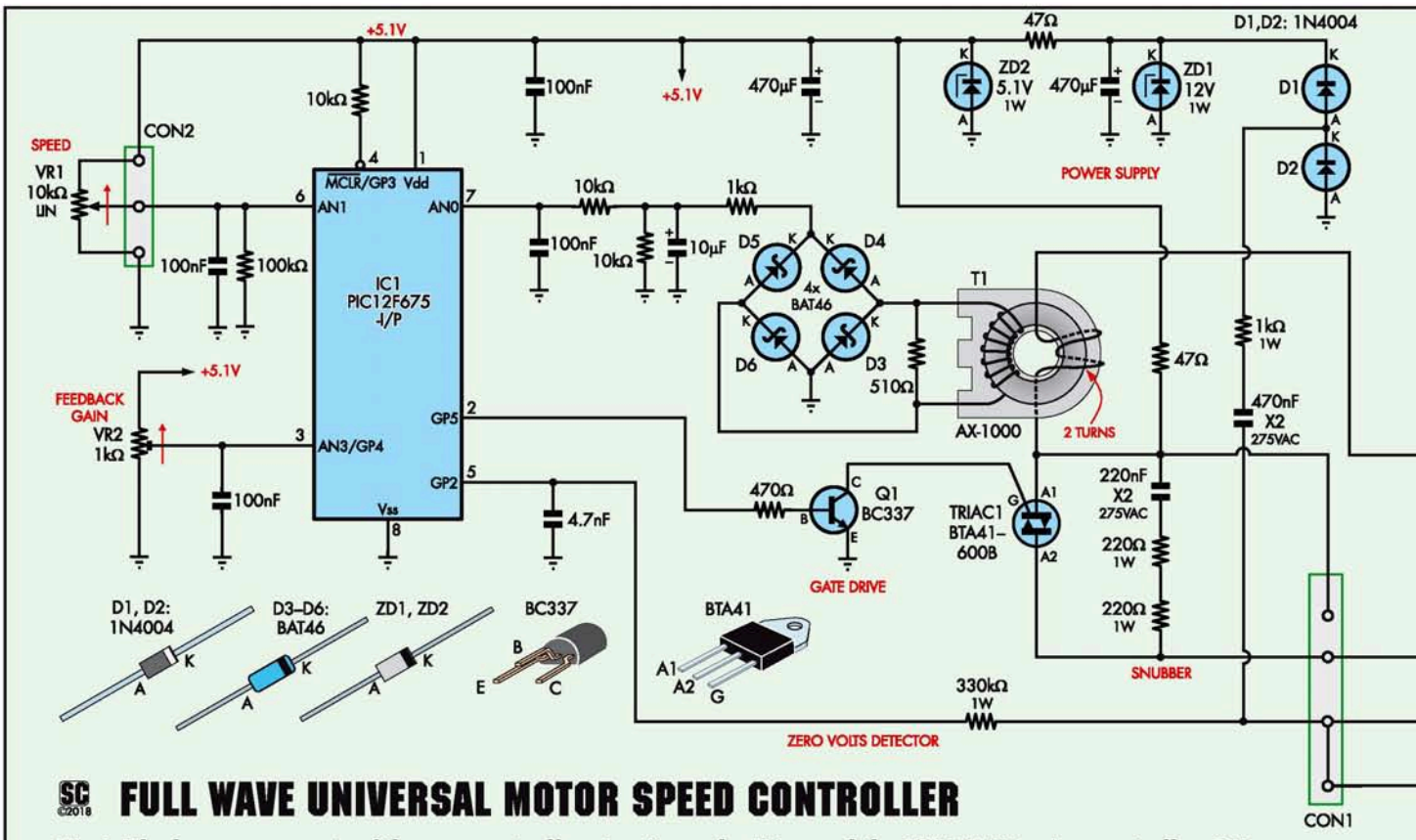


Scope2: the Speed Controller set for maximum output when driving an electric drill. There is considerable hash at the beginning of each positive half-cycle, caused by interaction between the drill's commutator and the Triac.

Phase control employs either an SCR (silicon controlled rectifier) for half-wave control or a Triac to provide full wave control, as used in "leading edge" dimmers.

Half wave control means that only one side of the mains waveform (the positive or the negative) is applied to the motor.

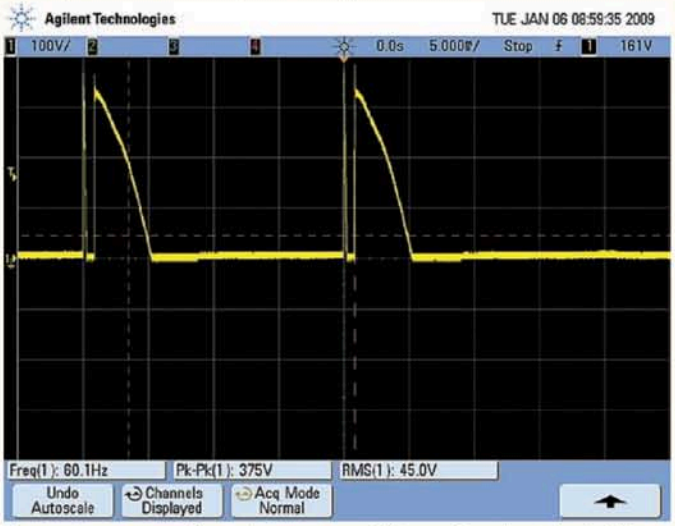
These devices are turned on by a trigger pulse applied to their gate electrodes and the term "phase control" comes about because the timing of the trigger pulses is varied with respect to the phase of the mains sinewave.



FULL WAVE UNIVERSAL MOTOR SPEED CONTROLLER

Fig.1: The key components of the new controller circuit are the Triac and the PIC12F675 microcontroller, IC1. IC1 monitors the speed potentiometer, VR1 at pin 6. It also monitors feedback gain potentiometer VR2, at pin 3, the current feedback via current transformer T1, at pin 7 and the mains waveform via a 330kΩ resistor at pin 5.

in fact, there is no comparison in performance!



Scope3: now set for a lower speed from the electric drill, the Triac is on for a shorter time and the RMS value of the waveform is considerably reduced to 45V. Note the frequency error caused by hash on the waveform.

Speed regulation

For a motor to have good low speed performance, the speed control circuit should compensate for any drop in motor speed as the load increases, by increasing power to the motor. Many simple SCR speed controllers rely upon the fact that a motor produces a back-EMF (electromotive force) which is proportional to its speed.

The circuit compensates for a drop in back-EMF by triggering the SCR earlier in the mains half-cycle and so applying more voltage to the motor.

In practice though, the back-EMF generated by most appliance motors is quite weak while the SCR is not conducting.

This is partly because there is no field current and the generation of voltage is only due to remnant magnetism in the motor core.

Furthermore, any back-EMF that is produced tends to be too late after the end of each half-cycle to have a worthwhile effect on the circuit triggering in the next half-cycle.

Our new Speed Control uses a different method to provide good speed regulation. It monitors the motor current to sense motor speed. If it senses a drop in speed, it increases the effective voltage to the motor.

From the general discussion above you can assume that our new design is significantly different to the February 2009 controller and although both use the same Triac.

The 2009 design uses the Triac as an SCR and the control to the motor is only half-wave.

Our new design uses the Triac to apply AC to the motor and it is triggered in both half-cycles of the mains waveform.

Unfortunately, the triggering requirements for correct operation with an inductive load such as a motor cannot be provided by a simple circuit.

In fact, the Triac must have multiple triggering pulses in each half-cycle and their timing is very critical. The only solution is to use a microcontroller.

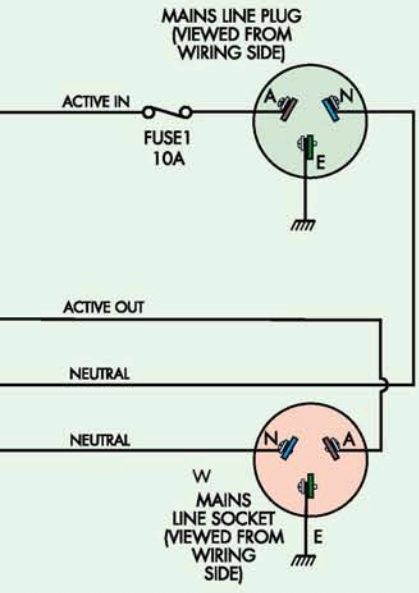
So let's have a look at the full circuit in Fig.1.

WARNING!

(1) This Speed Controller circuit operates directly from the 230VAC mains supply and contact with live components is potentially lethal.

(2) This circuit is not suitable for use with induction motors.

(3) Power tools with inbuilt fans must not be operated at low speeds for long periods, otherwise they may overheat.



Circuit description

The key components are the Triac and the PIC12F675 microcontroller, IC1. IC1 monitors the speed potentiometer, VR1 at pin 6. It also monitors feedback gain potentiometer VR2, at pin 3, the current feedback via current transformer T1, at pin 7 and the mains waveform via a 330kΩ resistor at pin 5.

In response to all those parameters, IC1 produces a series of pulses and these drive the NPN transistor Q1 and thence the gate of the Triac.

The Triac gate current flows via the 47Ω resistor connected between the 5.1V supply and the Triac's A1 terminal, then out through the gate and to circuit ground via Q1 (ie, the gate current is negative).

This method of connection places the 47Ω resistor between the 230VAC mains supply and the 5.1V supply which runs the PIC microcontroller. This arrangement has been used to avoid Triac switching noise getting into the 5.1V supply which can cause latch-up of the microcontroller.

Snubber network

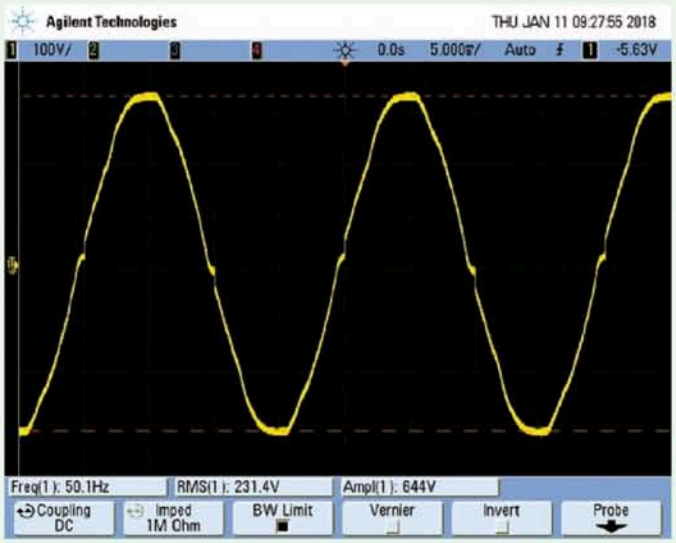
A snubber network comprising two 220Ω 1W resistors in series and a 220nF 275VAC X2-rated capacitor connected between the A1 and A2 terminals of the Triac. This network is there avoid rapid changes in voltage being applied to the Triac which would otherwiseit turn on (dV/dt switching) when it is supposed to be off.

These rapid changes in voltage can occur then power is first applied or can come from voltage transients generated by the inductance of the motor being controlled, each time the Triac turns off. In effect, the snubber network acts to damp transients and reduce their amplitude.

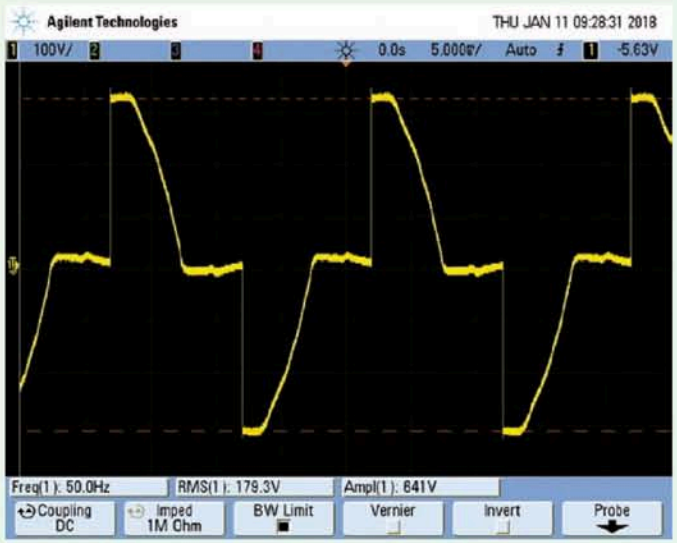
The DC supply for the microcontroller is derived directly from the 230VAC mains supply via a 470nF 275VAC X2 rated capacitor in series with a 1kΩ 1W resistor. The capacitor's impedance limits the average current drawn from the mains while the 1kΩ resistor limits the surge current when power is first applied.

It works in the following way. When the Neutral line is positive with respect to the Active line, current flows via the 470nF capacitor and diode D1 to the 470µF capacitor to

DRILL SPEED CONTROLLER PERFORMANCE WAVEFORMS



Scope4: this shows the waveform at maximum output. There is only a very short period (<0.4ms) at the beginning of each half-cycle when the Triac is off.



Scope5: here the output is set to about half, corresponding to an RMS voltage about 180V.
Scope 4, 5 and 6 are all with an incandescent lamp load.

charge it up. On negative half-cycles, the current through the 470nF capacitor is reversed via diode D2.

Zener diode ZD1 limits the voltage across the 470µF capacitor to 12V and that supply then feeds a second 470µF capacitor via a 47Ω resistor and its voltage is limited to 5.1V by zener diode ZD2. This is the supply for the microcontroller, IC1.

IC1 has its $\overline{\text{MCLR}}$ input (pin 4) tied to the 5.1V supply via a 10kΩ resistor and this provides a master clear (reset) for IC1 when power is applied. The main 5.1V supply for IC1 is decoupled with a 100nF capacitor.

VR1 is the speed potentiometer and it is connected across the 5.1V supply with the wiper connected to the pin 6, AN1 input. IC1 converts the voltage set by VR1 into a digital value using its internal analog to digital converter. The 100kΩ resistor from the wiper to ground holds the AN1 input at 0V, setting motor speed to zero should VR1's wiper go open-circuit.

Trimpot VR2 is also connected across the 5.1V supply and has its wiper monitored by the AN3 input of IC1 at pin 3. This voltage sets the gain of the feedback to maintain motor speed load. It is also converted to a digital value within IC1.

The 100nF capacitors at the wiper of VR1 and VR2 are there to provide a low source impedance for the analog to digital converter sample and hold input.

Mains synchronisation

Since the timing of the Triac's trigger pulses are so critical to its correct operation, IC1 needs to monitor the mains voltage. This is done by the GP2 input of IC1, at pin 5. This monitors the mains Neutral via a 330kΩ resistor and the signal is filtered with a 4.7nF capacitor.

An interrupt in IC1 occurs whenever the voltage chang-

What motors can be controlled?

We've noted elsewhere in this article that this controller suits the vast majority of power tools and appliances. These generally use universal motors and are series-wound motors with brushes. Incidentally, they're called universal motors because they can operate on both AC and DC.

You cannot use this Speed Control with any appliance which has an electronic speed control built in, whether part of the trigger mechanism or with a separate speed dial.

This does not apply to tools such as electric drills which provide a choice of two speeds via inbuilt reduction gears.

What about induction motors?

We have strongly warned against using any of our previous AC speed controls with induction motors, for two reasons.

First, the output of our previous designs is variable unfiltered DC – and that will not run an induction motor, which requires a variable supply frequency for its speed to be varied.

Second, connecting an induction motor to any of our previous speed controls usually resulted in serious circuit damage as well possibly burning out the induction motor itself.

That won't happen with this new Speed Control **but since it does not vary the mains frequency it cannot vary the motor speed**. You are unlikely to do any damage to the Speed Control though.

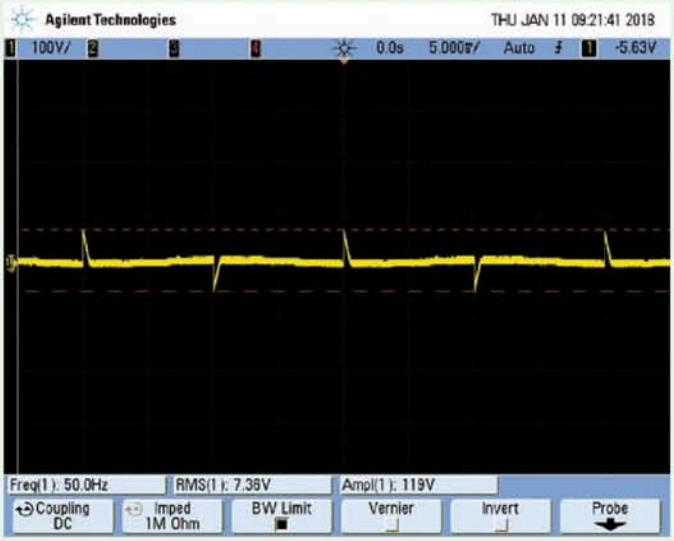
So how do you identify an induction motor?

Most induction motors used in domestic appliances will be 2-pole or 4-pole and always operate at a fixed speed, which is typically 2850 rpm for a 2-pole or 1440 rpm for a 4-pole unit. The speed will be on the nameplate. Bench grinders typically use 2-pole induction motors.

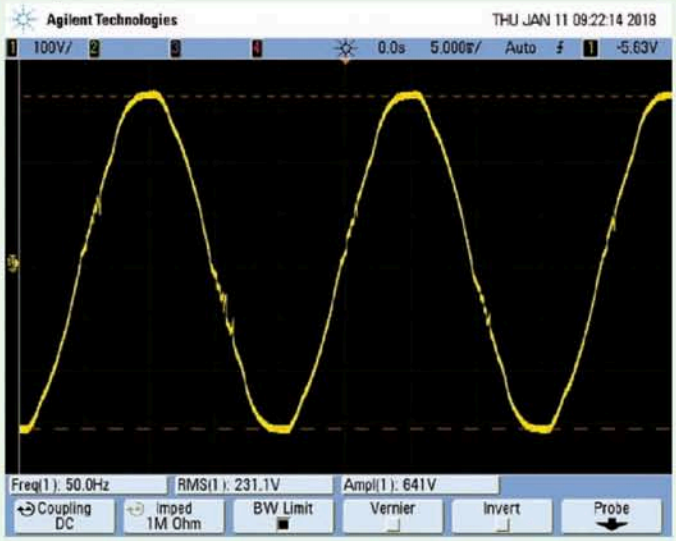
If you do need to control this type of motor, use the 1.5kW Induction Motor Controller published in April and May 2012. (www.siliconchip.com.au/Series/25).

Note that there are important modifications for that project, published in December 2012.

This series of scope grabs (and those overleaf) shows the Triac Speed controller working with a 150 watt incandescent lamp load and a Bosch 500W 2-speed drill. In each case, the connection to the output of the speed controller is made via a 100:1 probe. The waveforms are identical to those taken with a fully isolated differential probe.



Scope6: the output is set to the minimum whereby the Triac is still firing. The RMS voltage is 7.36V and the lamp filament is not even glowing.



Scope7: here the output is set to maximum but the load is the 500W drill. The hash on the waveform is due to the motor's commutator.

es from a high (around 4V) to a low level (around 1V) and also from a low to a high.

That interrupt level occurs when the mains voltage swings through zero volts in either direction. The interrupt tells IC1 that the voltage of the mains has just passed through 0V.

That allows IC1 to synchronise gate triggering with the mains waveform. Note that the 4.7nF capacitor at pin 5 introduces a phase lag (delay), but this is compensated for within IC1's software.

Current feedback

By now, you are probably wondering about the function of transformer T1 and the associated bridge rectifier. This is used to monitor the load current through the Triac. T1 is a current transformer comprising a ferrite toroid with a 2-turn primary winding in series with the Triac. The secondary winding has 1000 turns and it is loaded with a 510Ω resistor.

With this loading, the transformer produces a voltage of 800mV per amp of load current which is the current through the motor being controlled.

This voltage is fed to the bridge rectifier consisting of four schottky diodes and the resulting DC is filtered with a 10µF capacitor.

The 1kΩ series resistor provides the attack time for the resulting current feedback signal while the 10kΩ resistor provides the decay, discharging the capacitor over time.

The current feedback signal is monitored at the AN0 input at pin 7 and the associated 10kΩ resistor and 100nF capacitor provide extra filtering, as well as limiting any current into the internal protection diodes at pin 7.

So transformer T1 provides the current feedback signal for IC1 which gives motor speed regulation and trimpot VR2 is gain control for that function. You set VR2 to give the optimum speed regulation for the power tool you are controlling.

Construction

With the exception of VR1 (the speed control potentiometer), the Full Wave Universal Motor Speed Controller is constructed entirely on a double-sided, plated-through PCB (printed circuit board) coded 10102181 and measuring 103 x 81mm.

This is mounted inside a diecast box measuring 119 x 94 x 34mm.

Follow the overlay diagram shown in Fig.2.

Assembly can begin by installing the resistors. The resistor colour codes are shown in a table but you should also double-check each resistor using a digital multimeter.

Following this, fit the diodes, which must be orientated as shown. Be careful: there are several different diode types – 1N4004 for D1 and D2 and BAT46 for D3 to D6; zener diodes are a 12V 1W type (1N4742) for ZD1 and a 5.1V 1W type (1N4733) for ZD2.

If you get any of these mixed up, the circuit will not operate.

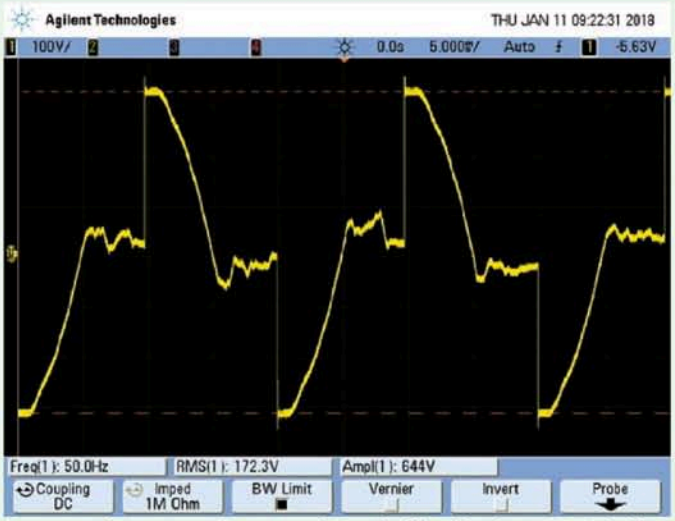
IC1 is mounted on an 8-pin DIL socket so install this socket now, taking care to orientate it correctly, with the notch facing towards the top of the PCB.

Leave IC1 out for the time being though – we'll fit it later on. Q1 can be installed now.

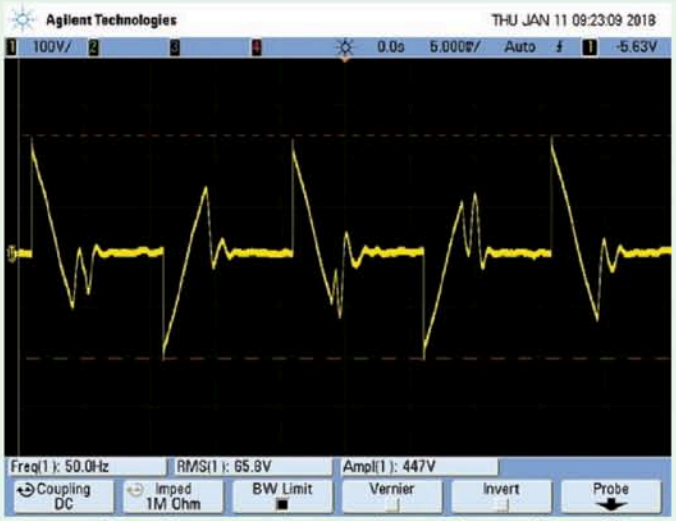
Capacitors are placed next. The MKT capacitors and the polypropylene types usually use a code for the value. These are all shown in the capacitor code table. By contrast, electrolytic capacitors are almost always marked with their value (in µF) along with their polarity (usually the negative lead is marked with a stripe). They must be inserted with the polarity shown.

The screw terminals are next. The 3-way terminal block for CON2 is installed with the lead entries toward the lower edge of the PCB.

Finally (for now), install the current transformer, T1. It does not matter which way it is oriented. The Triac is fitted later.



Scope8: the output is set to about half with the 500W drill as a load. The RMS voltage is just less than 180V, the maximum you could expect with a conventional half-wave SCR speed control.



Scope9: here the output is set to the minimum that will give useful smooth low speed running from the drill. Again, the severe hash on the waveform is due to the motor's commutator.

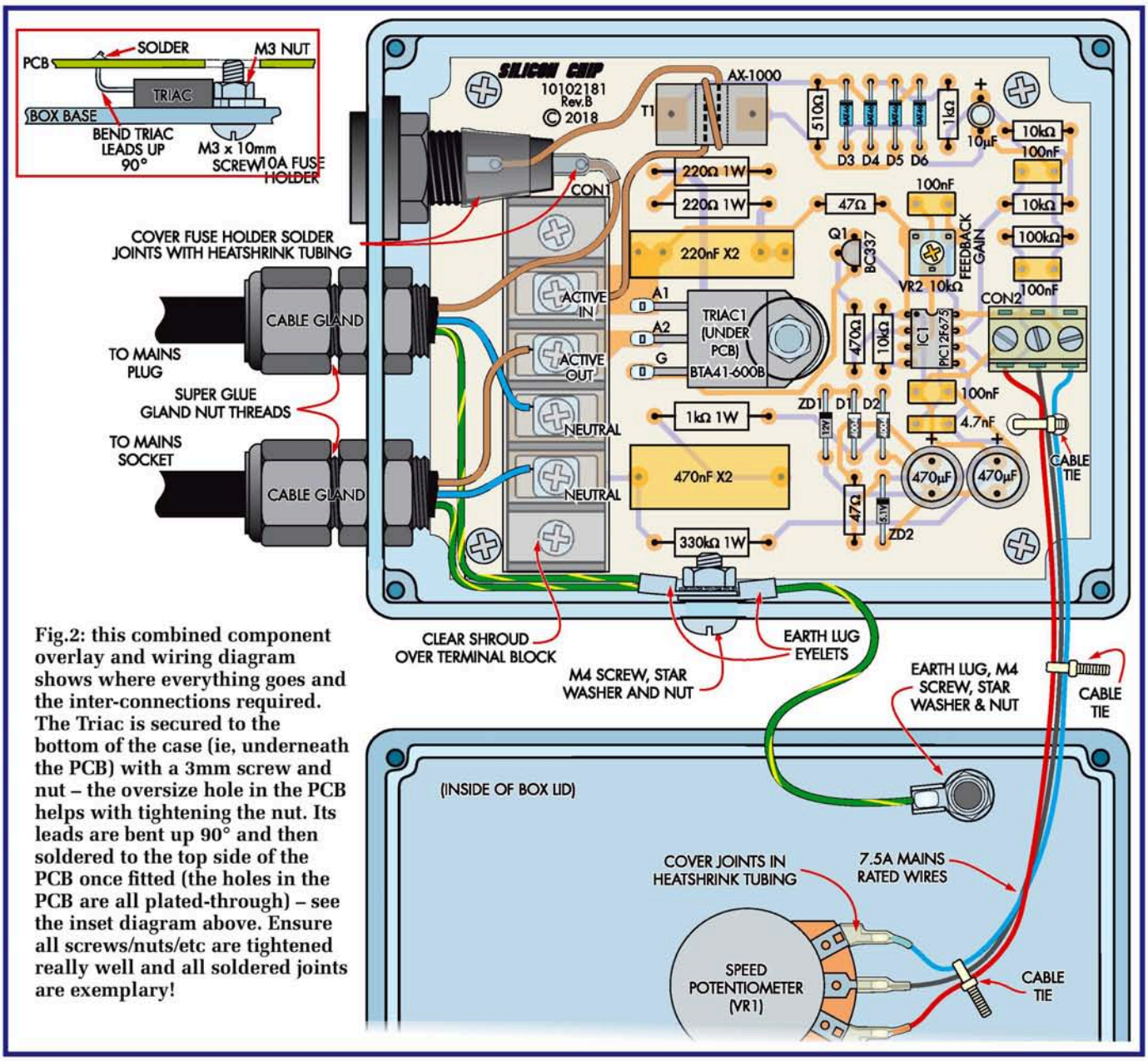
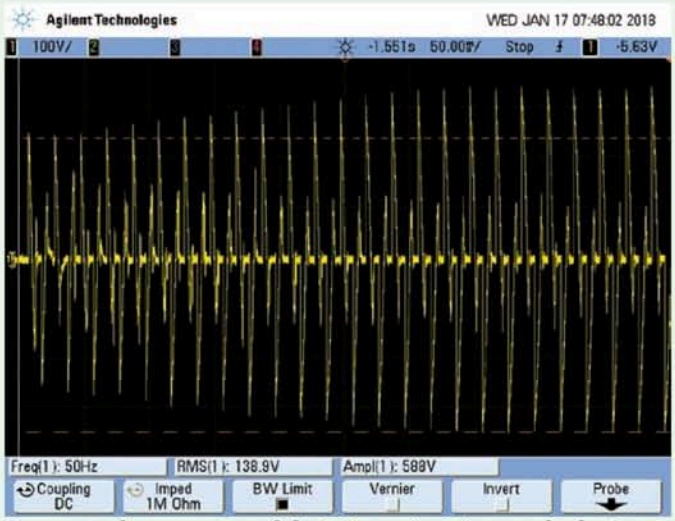


Fig.2: this combined component overlay and wiring diagram shows where everything goes and the inter-connections required. The Triac is secured to the bottom of the case (ie, underneath the PCB) with a 3mm screw and nut – the oversize hole in the PCB helps with tightening the nut. Its leads are bent up 90° and then soldered to the top side of the PCB once fitted (the holes in the PCB are all plated-through) – see the inset diagram above. Ensure all screws/nuts/etc are tightened really well and all soldered joints are exemplary!



Scope10: the ramp-up of the Triac triggering angle during soft startup. The full ramp-up takes more than one second.

Drilling the case

Further construction requires drilling holes in the die-cast enclosure. A template is shown in Fig.4 for the end and side panel drilling details. The lid requires a 9.5mm diameter hole for potentiometer VR1 and a 4mm hole for the earth screw hole.

The PCB is mounted on the base of the case using M3 tapped spacers that are 6.3mm (or 8mm) long. Holes are required for these mounting holes on the base of the case.

The CON1 screw terminal end of the PCB sits further away from the end of the box compared to the other end. This allows space for the cable gland nuts. Position the PCB in the case to use as a template and mark out the hole positions and drill out to 3mm.

Attach the 8 or 6.3mm long spacers to the PCB. Then bend the triac leads up at 90° 4mm from the body of the triac. Insert the leads into the PCB from the underside. If you are using 6.3mm spacers, the underside pigtail leads from the components must be cut short to prevent close contact with the base of the case. They should be trimmed anyway regardless of the spacer length.

The PCB can be secured to the case with screws from the underside into the tapped spacers. Mark out the triac mounting hole position on the base of the case.

Remove the PCB again and drill out to 4mm. Clean away any metal swarf and slightly chamfer the hole edges. Re-attach the PCB and adjust the Triac lead height so the metal tab sits flush onto the flat surface.

Secure the Triac with the M3 screw and nut. The metal tab is internally isolated from the leads and so does not require any further insulation between its tab and case. Solder the Triac leads on the top of the PCB and trim the leads close to the PCB.

Now remove the screws to gain access to the underside of the PCB and solder the triac leads from the underside of the PCB. The four rubber feet can be attached to the base of the case now.

Two holes are required in the lid – one for the speed control pot (9.5mm) and the other for the earth screw (4mm).

If you use a countersunk-head earth screw and counter-

Parts list – Full Wave Universal Motor Speed Controller

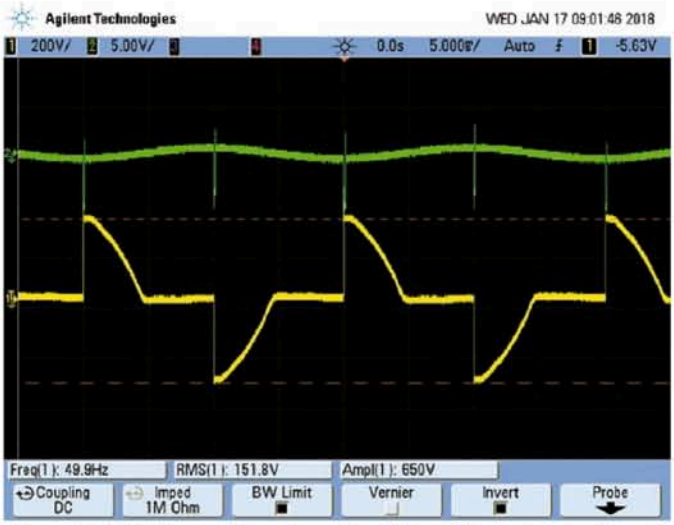
1 PCB coded 10102181, measuring 103 x 81mm
1 diecast box 119 x 94 x 34mm [Jaycar HB-5067]
1 Talema AX-1000 10A current transformer (T1) [RS Components 775-4928]
1 M205 10A safety panel mount fuse holder (F1) [Altronics S5992]
1 M205 10A fuse
1 4-way PCB mount terminal barrier (CON1) [Jaycar HM-3162]
1 3-way PCB mount screw terminals with 5.08mm spacings (CON2)
2 cable glands for 5-10mm cable
1 DIL-8 IC socket
1 2m 250V 10A mains extension lead (cut in half to form mains input and output leads)
4 4mm eyelet lugs
4 8mm or 6.3mm M3 tapped Nylon standoffs
1 M3 x 10mm screw (for triac mounting)
1 M3 nut and washer
2 M4 x 10mm screws (CSK head preferred)
2 4mm ID star washers
2 M4 nuts
8 M3 x 5mm screws
4 stick-on rubber feet
1 20mm length of 12mm diameter heatshrink tubing
1 80mm length of 3mm diameter heatshrink tubing
1 25mm length of 6mm diameter green heatshrink tubing if required for chassis lugs
3 150mm lengths of 7.5A mains-rated wire for VR1
3 100mm long cable ties

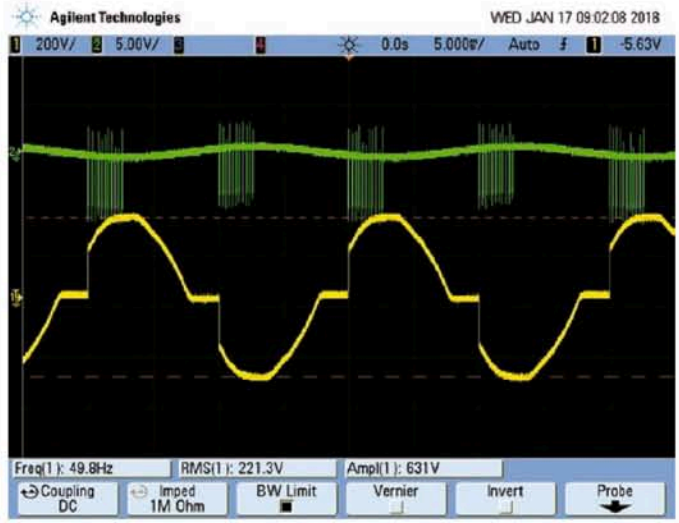
Semiconductors
1 PIC12F675 programmed with 1010218A.hex (IC1)
1 BTA41-600B insulated tab 40A 600V Triac (Triac1) [element14 1057288 or RS 687-1007]
1 BC337 NPN transistor (Q1)
1 12V 1W (1N4742) zener diode (ZD1)
1 5.1V 1W (1N4733) zener diode (ZD2)
2 1N4004 1A diodes (D1,D2)
4 BAT46 schottky diodes (D3-D6)

Capacitors
2 470µF 16V PC electrolytic
1 10µF 16V PC electrolytic
1 470nF 275VAC X2 class
1 220nF 275VAC X2 class
4 100nF 63V or 100V MKT polyester
1 4.7nF 63V or 100V MKT polyester

Resistors (0.25W, 1% unless specified)
1 330kΩ 1W carbon film
1 100kΩ
3 10kΩ
1 1kΩ
1 1kΩ 1W carbon film
1 510Ω
1 470Ω
2 220Ω 1W carbon film
2 47Ω
1 linear 10kΩ 24mm potentiometer (VR1)
1 10kΩ mini, top adjust trimpot (3386F style) (VR2)

Miscellaneous
1 knob to suit VR1
Super glue, heatsink compound, solder





Scope11&12: these show how the Triac triggering varies, depending on the speed setting. At low speed settings, there is only one trigger pulse during each mains half-cycle. At higher power levels, there are multiple trigger pulses during each half-cycle to ensure that the Triac stays turned on, in spite of the lagging load current (due to the inductive motor load).

sink the earth screw hole appropriately, it can be mounted **under** the panel label (looks neater!). Otherwise, you'll need to cut holes in the panel label (with a sharp hobby knife) when the label is stuck on.

The panel label file can be downloaded (free for subscribers) from our website (www.siliconchip.com.au).

To produce a front panel label, you have several options. For a more robust label, print as a mirror image onto clear overhead projector film (using film suitable for your type of printer). Attach the label printed side down to the lid with a light coloured or clear silicone sealant.

Alternatively, you can print onto a synthetic "Dataflex" sticky label that is suitable for inkjet printers or a "Datapol" sticky label for laser printers. Then affix the label using the sticky back adhesive.

(There's more information on Dataflex at siliconchip.com.au/link/aabw and Datapol at siliconchip.com.au/link/aabx And there's a few more hints on making labels for projects – see siliconchip.com.au/Help/FrontPanels).

The lid, with front panel affixed, "opens out" from the box as shown in this photo, reproduced about three-quarter size. Make sure the wires to the speed pot are all 250VAC mains-rated (don't use rainbow cable!) and use cable ties and heatshrink where shown above and in Fig.2.

Wiring

Cut the 10A extension lead into two to provide one lead with a plug on the end and another with a socket. Where the lead is cut depends on how long you prefer each lead.

You may prefer a long plug cord and short socket lead so the motor appliance is located near to the controller, or the lead can be cut into two equal lengths.

Before cutting make sure you have sufficient length to strip back the insulation as detailed in the next two paragraphs.

Make sure the plug lead and socket lead are placed in the correct gland and wired as shown.

First the socket (output) lead: you need a 100mm length of earth wire (green/yellow stripe) for the connection between the chassis and lid, so strip back the outside sheath insulation by about 200mm. Then cut the blue

Three holes are required in the end of the case – the two on the right are 15mm to suit the cable glands, while the hole on the left is nominally 12.5mm but is "D" shaped to hold the fuseholder in place. On the lid, a 9.5mm hole to house the speed control pot sits slightly off-centre with a 4mm hole (on the left in this photo) for the lid earthing screw. As mentioned in the text, if this hole is shaped to accept a countersunk-head screw, it can go underneath the label and so not be visible.

Fig.3: the same-size front panel artwork which is designed to be glued to the case lid. It can be copied, or downloaded (free for subscribers) from siliconchip.com.au

neutral wire and brown active wires to 50mm and connect them to their respective terminals on the terminal block.

You should be left with 100mm of earth wire (green/yellow stripe) which is routed around the edge of the PCB and twists with the earth wire from the plug (input) lead to be crimped into one of the earth lugs.

The spare 150mm brown wire can be used later to connect from the fuse to the CON1 terminal via the transformer, T1. This has two turns of the active wire looped through the transformer hole.

The plug lead outside sheath insulation should be stripped back to expose 100mm of wire. This leaves sufficient lead length. All three wires are passed through the cable glands and connect as shown in Fig.2. Cut the neutral wire to 50mm and strip back the insulation before connecting the neutral (blue) wire to the terminal block

The active (brown) wire solders direct to the fuseholder. 10mm diameter heatshrink tubing should first be placed over active (brown) wire which slides up and over the fuseholder after soldering to cover the side fuseholder terminal.

Similarly, 3mm diameter heatshrink tubing 3mm in diameter is used to cover the fuseholder end terminal. Once both connections are soldered, pass the heatshrink over the join and shrink.

Now twist the ends of the input earth (green/yellow stripe) wire and the output earth wire together and crimp into one of the eyelet earth lugs.

Cut VR1's shaft to 12mm long and file the edges smooth. Then attach the three 100mm lengths of 7.5A mains rated wire to the three VR1 terminals and cover with the 3mm heatshrink tubing. The other ends connect to CON2.

These wires are secured using a cable tie that feeds through holes in the PCB. Attach VR1 to the lid of the case – note that the potentiometer must be located as shown (ie, leads emerging from the right) so it fits between the two mains rated capacitors on the PCB.

Fit the knob – you may need to lift out the knob cap with a hobby knife and re-orient the cap so its pointer position matches the rotation marks on the panel.

That 100mm length of earth wire you cut off from the output lead can now be crimped into two eyelet lugs, which are screwed to the underside of the box lid and the earth screw on the side of the case using

Resistor Colour Codes

Qty	Value	4-Band Code (1%)	5-Band Code (1%)
❑ 1^	330kΩ	orange orange yellow brown	orange orange black orange brown
❑ 1	100kΩ	brown black yellow brown	brown black black orange brown
❑ 3	10kΩ	brown black orange brown	brown black black red brown
❑ 1+1^	1kΩ	brown black red brown	brown black black brown brown
❑ 1	510Ω	green brown brown brown	green brown black black brown
❑ 1	470Ω	yellow purple brown brown	yellow purple black black brown
❑ 2^	220Ω	red red brown brown	red red black black brown
❑ 2	47Ω	yellow purple black brown	yellow purple black gold brown

^ = 1W, carbon film type

Small Capacitor Codes

Qty	Value/Type	EIA	IEC
❑ 1	470nF X2	474	470n
❑ 1	220nF X2	224	220n
❑ 4	100nF MKT	104	100n
❑ 1	4.7nF MKT	472	4n7

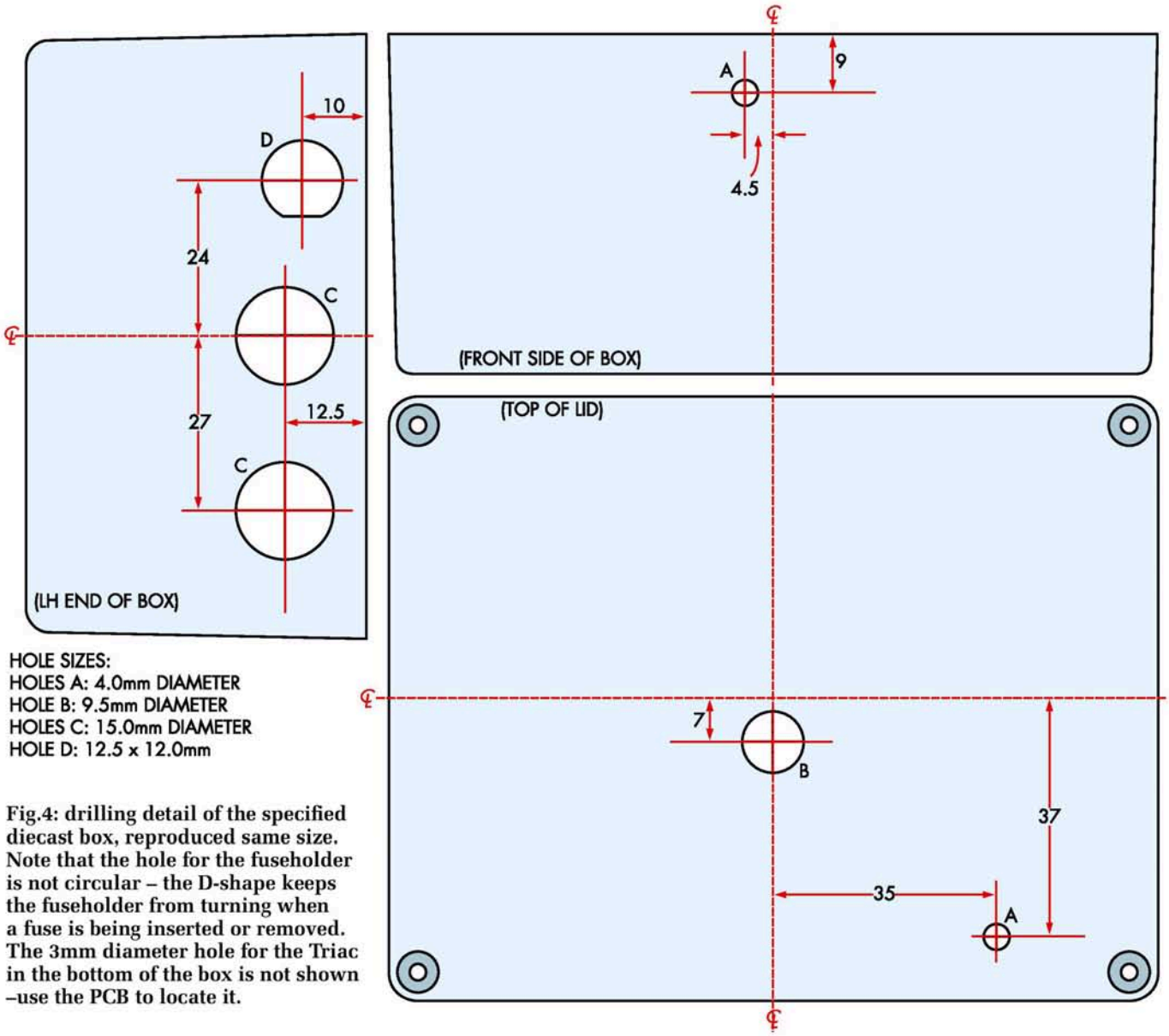


Fig.4: drilling detail of the specified diecast box, reproduced same size. Note that the hole for the fuseholder is not circular – the D-shape keeps the fuseholder from turning when a fuse is being inserted or removed. The 3mm diameter hole for the Triac in the bottom of the box is not shown –use the PCB to locate it.

M4 screws, star washers and nuts. Ensure that the nuts are fully tightened.

Final assembly

Apply a smear of heatsink compound to the underside of the Triac before installing the PCB inside the case. Again, the tab of the Triac is insulated, so it can contact the case with safety.

The last components to inserted are IC1 (taking care it is oriented correctly), the 10A fuse into its holder and the cover for the barrier terminals (CON1) – it is simply pressed on to cover the screw terminals. Finally, rotate VR2 fully anticlockwise to initially disable feedback.

Check your construction carefully and especially check that the earth wires (green/yellow striped) actually connect together the case, the lid and the earth pins on both the mains plug and socket. Check this with a multimeter set to read low ohms.

The cable glands need to be tightened to hold the mains cords in place. Because these are easily undone, the thread of the glands should have a drop of super glue applied to the threads before tightening. This way the glands cannot be undone. Attach the lid to the case using the four screws supplied with the case (don't be tempted to run the speed controller without the lid in place!).

Testing

Connect up a universal motor appliance (eg, an electric drill) to the controller, apply power and check the motor can be controlled when adjusting the speed potentiometer.

Once you have verified that it works, **switch off power and unplug the mains plug** from the mains outlet. Then remove the lid and adjust VR2 half way. Re-attach the lid and apply power again and check the speed regulation of the motor under load.

Trimpot VR2 may need further adjustment; anticlockwise if the motor speeds up under load and clockwise if the speed drops off too markedly under load.

Note that any adjustment of VR2 must **only** be done with the power off and mains plug disconnected. This means that adjustment is a trial and error process. Power should only re-applied after the lid is re-attached. SC

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Drift-free Induction Balance Metal Detector

Induction Balance (IB) metal detectors with concentric search heads are very popular as they have a high sensitivity and allow you to pinpoint the detected object. The simplest such instruments are based on a low-frequency RF oscillator tied to transmit coil(s), a pickup coil feeding the RF pre-amplifier, a peak detector, DC amplifier and an audio amplifier.

The problem with this approach is that the RF oscillator must be very stable or the instrument must be continuously adjusted. Also, thermal drift of the signal diodes used in the peak detector can affect their operation.

This design overcomes both problems by using a ceramic resonator to stabilise the RF oscillator and by employing pulsating DC current in the transmit coils, eliminating the need for a peak detector to rectify the received signal.

It can sense a coin at a distance of around 200mm and a larger object (400mm in diameter) 700mm away in free air. It is equipped with a discriminator section that can be set to non-ferrous (Mode 1) or ferrous (Mode 2) detection with a momentary press of the mode selector pushbutton.

The detector is built around a 4060B oscillator and a frequency divider (IC1), a TL064 quad op amp (IC2) and two gates of a 4066B quad bilateral switch (IC3). An ATmega8 microcontroller with a 16x2 alphanumeric LCD module and a series of LEDs is used to indicate the detector status.

IC1 forms the primary oscillator. Its frequency is set to 455kHz by ceramic resonator X1, which is accompanied by two 220pF load capacitors. Output pin 4 of IC1 (O5) provides a frequency which is 1/64th of the oscillator, which in this case is 7.1kHz.

This signal is then fed to control pin 13 of bilateral analog switch IC3a, causing it to dump the 5V charge across the 100nF capacitor at pin 1 through transmit coils L1 and L2 about 7,100 times per second.

These DC pulses cause a pulsating magnetic field around transmit coil L1 and bucking coil L2, which are wound in opposite directions and connected in series.

Under no-target conditions, their induced magnetic fields cancel each other out and so nothing is picked up by receive coil L3. But when a metallic object is inside the magnetic field, the balance of these magnetic fields is affected, resulting in a voltage appearing across L3. This is fed to a differential amplifier based around op amp IC2c and appears as an output signal at its pin 8.

The two 330nF capacitors in series across L3 (effectively, a single 165nF capacitor) cause it to be resonant at the expected signal frequency, rejecting external interference and maximising signal pick-up. The differential amplifier has a gain of around 94 times (220kΩ ÷ 4.7kΩ × 2).

The signal from IC1 which controls when the pulses are applied to the transmit coils is also fed to both inputs (pins 5 & 6) of op amp IC2b. However, the signal to non-inverting input pin 5 is delayed by an RC low-pass filter with a time constant of 2.2kΩ x 4.7nF = 10µs.

That causes output pin 7 of IC2b to go high a short time after output O5 of IC1 goes high (ie, when the pulse is applied to the transmit coils) and it stays high for a short time after output O5 goes low again.

This signal is used to control another analog switch, IC3b, which gates the output of differential amplifier IC2c so that it's only fed to the following amplifier stage, IC2d, during this window period. This preserves the polarity of the received DC voltage pulses and is necessary for the micro to provide the ferrous/non-ferrous metal discrimination function.

IC2d further amplifies the resulting signal by a factor of 48 and also provides some low-pass filtering due to the 33nF capacitor across its feedback resistor. The signal then passes to sensitivity adjustment potentiometer VR1 and another low-pass filter. The resulting DC signal then goes to analog input ADC5 (pin 28) of micro IC4.

IC4 converts this analog signal into a number, then displays the received voltage at right-hand side of the top line on the LCD, reading 0-5V DC. When a metal object is detected, the micro also uses the change in DC voltage to light up one of ten LEDs, LED1-LED10, giving an indication of the size and closeness of the metal object with LED1 indicating the weakest signal and LED10 the strongest.

The micro also drives its PWM output at PB1 (pin 15) to produce an AC waveform which is fed to an RC low-pass filter and thence to a 4046 voltage-controlled oscillator, IC5. Depending on the PWM duty cycle and thus the voltage at pin 9 of IC6, it produces a tone which is then fed to the piezo sounder, to be heard by the operator.

The sounder is silent when nothing has been detected. If the search head detects an object, LED1 lights up and the piezo audio frequency is set to 700Hz. It rises in steps of 120Hz, up to 2500Hz, as the voltage from the metal detection circuitry increases.

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We will pay good money to feature it in Circuit Notebook. We can pay you by electronic funds transfer, cheque or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

Thus, the VCO generates 16 distinct tones for objects producing weaker or stronger magnetic fields or buried at different depths.

When the LEDs light up, a corresponding 16-step bargraph is also displayed on the second line of the LCD.

Power is from a 9V battery, switched by S1, with reverse polarity protection diode D1. A 78L05 regulator reduces the battery voltage to a steady 5V for the rest of the circuit.

The search head includes transmit coil L1, receive coil L3 (half the diameter of the transmit coil) and bucking coil L2 which is wound on top of the receive coil. All three coils are wound using 0.315mm diameter (30SWG) enamelled copper wire.

L1 consists of 80 turns wound anti-clockwise on a 140mm diameter former (eg, a piece of plastic conduit). Once complete, remove the completed coil from the former and wrap it with insulating tape.

Receive coil L3 is made using 160 turns wound anti-clockwise (just like L1) on a 70mm diameter former. Bucking coil L2 consists of 27 turns wound clockwise directly on top of the receive coil.

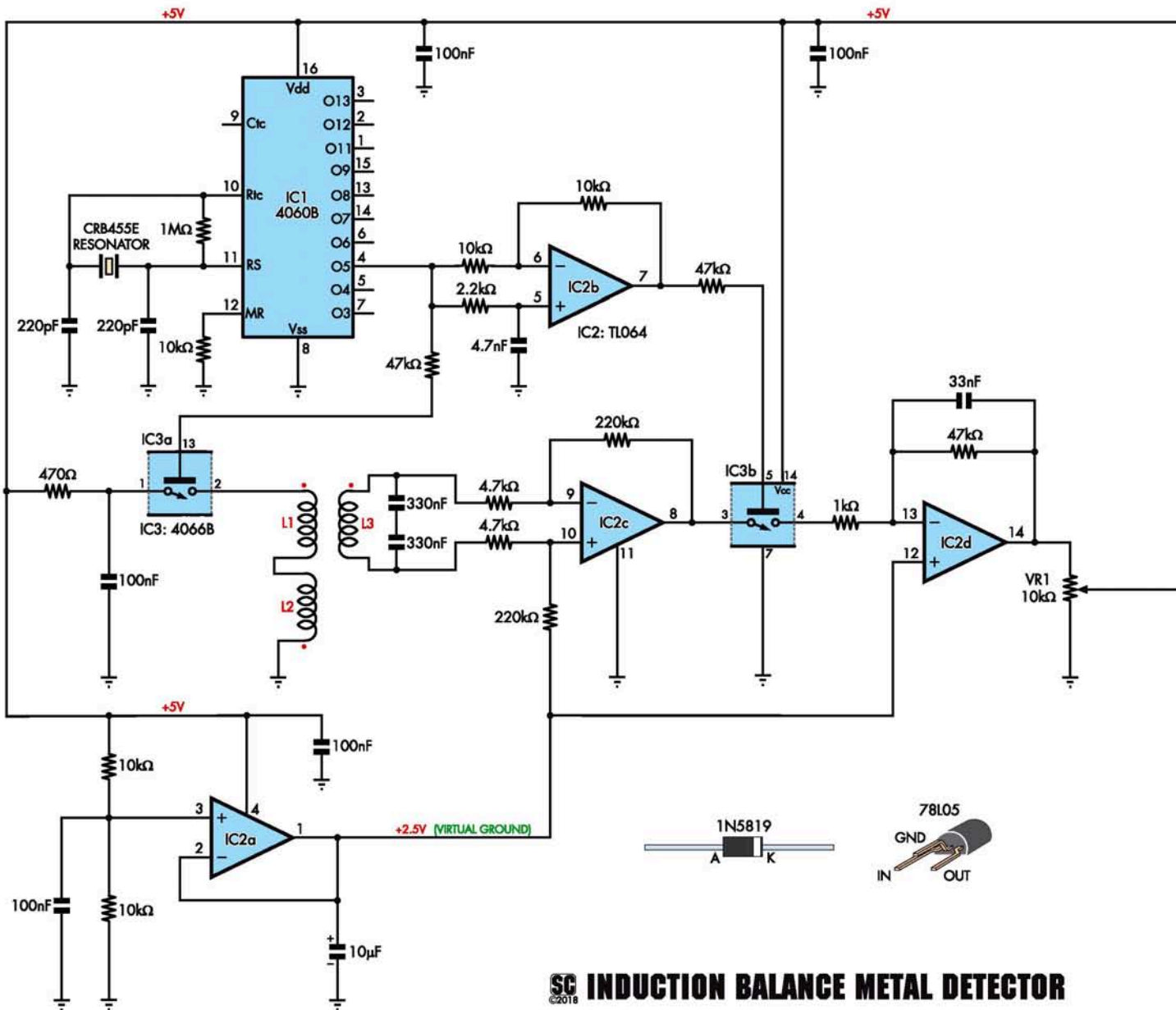
Remove the double coil L2/L3 from the former, then secure them together using strips of insulating tape. Leave a moveable loop of about one half-turn of wire from L3. This will be moved around later, to get a good null when the coils are being balanced.

Once the three coils have been made, cut a 160mm diameter circle from 3mm plywood or similar. Mount L1 and then the double coil L2/L3 at its centre. All the three coils are positioned coplanar and concentric with one another so that they are all centred on a common axis. Connect the coils to the circuit according to the schematic.

Notice that the bucking coil L2 is connected in series with the transmit coil L1 but with its phase reversed. The most sensitive part of the search head is the area under the receive coil.

For more details on the construction of coplanar concentric coils, refer to US patent 4293816 or visit this site: **siliconchip.com.au/link/aait**

Having built the unit, you will need to program microcontroller IC4. The software is written in BASIC and a



SC INDUCTION BALANCE METAL DETECTOR

HEX file is supplied along with it. This was generated from the BASIC code using BASCOM for Atmel AVR. A free trial of this compiler is available at siliconchip.com.au/link/aacw

Upload the HEX file to the ATmega chip using a compatible programmer, then set VR1 to maximum, place the search head well away from any metal object and switch the detector on.

It starts up in non-ferrous mode 1, which should cause non-ferrous metallic objects to be picked up and ferrous objects to be rejected. The current mode is shown on the left-hand side of the first line of the LCD.

Move around the half-turn moveable loop of the bucking coil L2 until the ADC voltage on the right-hand side of the first line of the LCD reads 2.20-2.25V. Then fix the moveable coil in place using glue. Turn VR1 down until the ADC idle voltage on the LCD is between 1.95 and 1.99V. The sounder falls silent when the ADC voltage is below 2.00V DC.

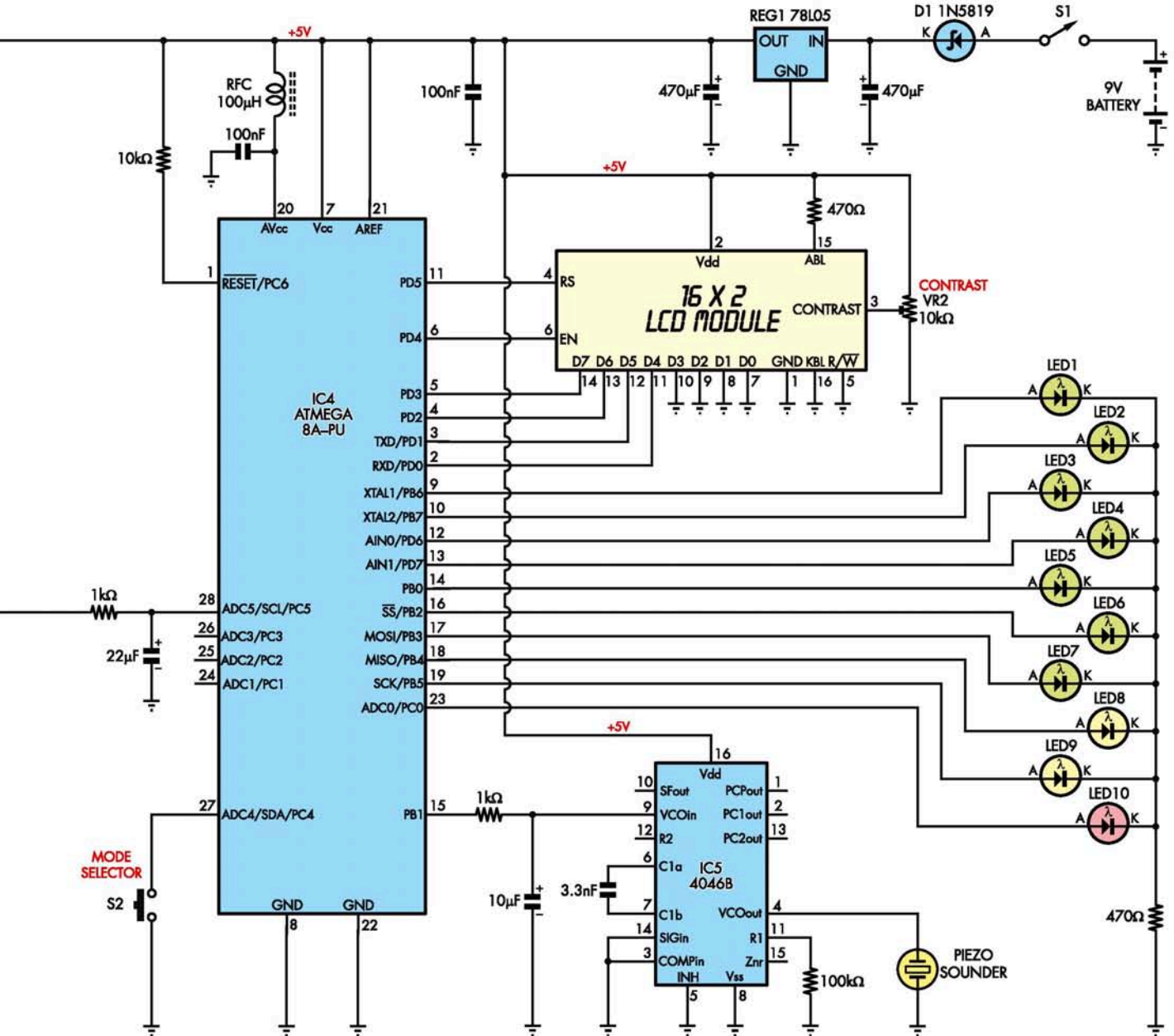
Now bring a coin close to the centre of the search head. The ADC voltage should increase and LED1 should light up. At the same time, the sounder should produce a tone. The closer you bring the coin to the search head, the higher will be the frequency of the audio output and the higher the number of the LED that lights up. Only one of the LEDs is on at a time.

The bargraph on the second line of the LCD also proceeds proportionately from the left to right as the strength of the field increases. With the strongest signal, LED10 will light up, the sound frequency will be 2500Hz and the bargraph will fill the width of the LCD.

Now push mode switch S2 to cause the circuit to switch to the ferrous metal detection mode, mode 2. Turn VR1 up to set the ADC idle voltage to 2.01 to 2.05. In this mode, when the ADC voltage is above 1.99, the sounder falls silent. Bring a small ferrous object, like an iron screw or bolt, close to the search head. The ADC voltage decreases but LED1 will light up and the sounder will produce a tone.

As the ferrous object is brought closer, the other LEDs will light up in turn and the tone will increase in pitch. The bargraph also proceeds to the right.

Mahmood Alimohammadi, Tehran, Iran. ($80)



Colour slideshow with alarm clock using an ESP32

A few years ago, I hooked a Raspberry Pi up to a 3.5-inch TFT display to use as a digital picture frame/slide show. It loaded pictures from the SD card in the Raspberry Pi and displayed them in sequence.

This is a cheaper, simpler version of that project with even more features. It uses just a few low-cost modules, including an ESP32 microcontroller module with onboard WiFi, to display a series of images as well as an "analog" clock and it can be used as an alarm clock too.

This version uses a 3.2-inch colour TFT based on the ILI9341 controller. This is similar to the touchscreen used in the Micromite LCD BackPack from the February 2016 issue (siliconchip.com.au/Article/9812) except that it has no touch sensor.

The same circuit and code should work with a variety of screens based on this chip.

One advantage of using the ESP32 is that it starts up instantly and is very reliable. By comparison, the Raspberry Pi takes some time to boot since it's running a fully-fledged operating system. That also means there's more to go wrong.

I used the Adafruit display library for Arduino and this incorporates a bmpDraw() function which makes it easy to load and display an image.

To add the clock function, I wired up a DS3231-based real-time clock module. This is the same module which has been used in several Silicon Chip projects and it incorporates an onboard battery back-up to keep the time correct.

Its internal crystal is very accurate so it doesn't suffer from much drift over time.

I also wired up a piezo buzzer between pin D14 of the ESP32 and ground, and used the WriteTone() function to drive this at a particular frequency for the alarm clock function.

The clock is drawn on the screen like an analog clock, the date, day of the week and temperature (as determined by a sensor on the DS3213 module) are shown as text on the clock face.

The wiring of the modules is fairly straightforward, with the display and microSD card module sharing the same SPI bus consisting of shared MISO (data in), MOSI (data out) and SCK (clock) pins which go to D19, D23 and D18 on the ESP32 respectively. They have their own CS (chip select) pins, with the LCD wired to D4 and the microSD card to D13.

The LCD also has a DC (data/command) pin and reset pin, which are wired to D15 and D2 on the ESP32 micro. The DS3231 module uses I^2C communications so its SDA (data) pin goes to D21 while its SCL (clock) pin goes to D22.

The remainder of the pins are V_{CC} and GND which are simply wired to 3.3V and GND respectively on each device.

All these devices will run off 3.3V. The LCD I used has an integrated 3.3V regulator so it can run off 3.3V or 5V. The ESP32 also has an internal regulator to derive the 3.3V rail from a 5V USB supply. A 10µF bypass capacitor helps filter this rail. The unit can be run from a USB charger or similar.

I built my unit on protoboard with the ESP32 module soldered to one side and the SD card shield and TFT display on the other.

Some ILI9341-based LCD screens have an onboard SD card holder and you could use this instead of the separate module. The total cost of all the modules in my prototype is around US$22.

The software is compiled and uploaded to the ESP32 using the Arduino IDE. The sketch and all required libraries can be downloaded from the Silicon Chip website, free for subscribers.

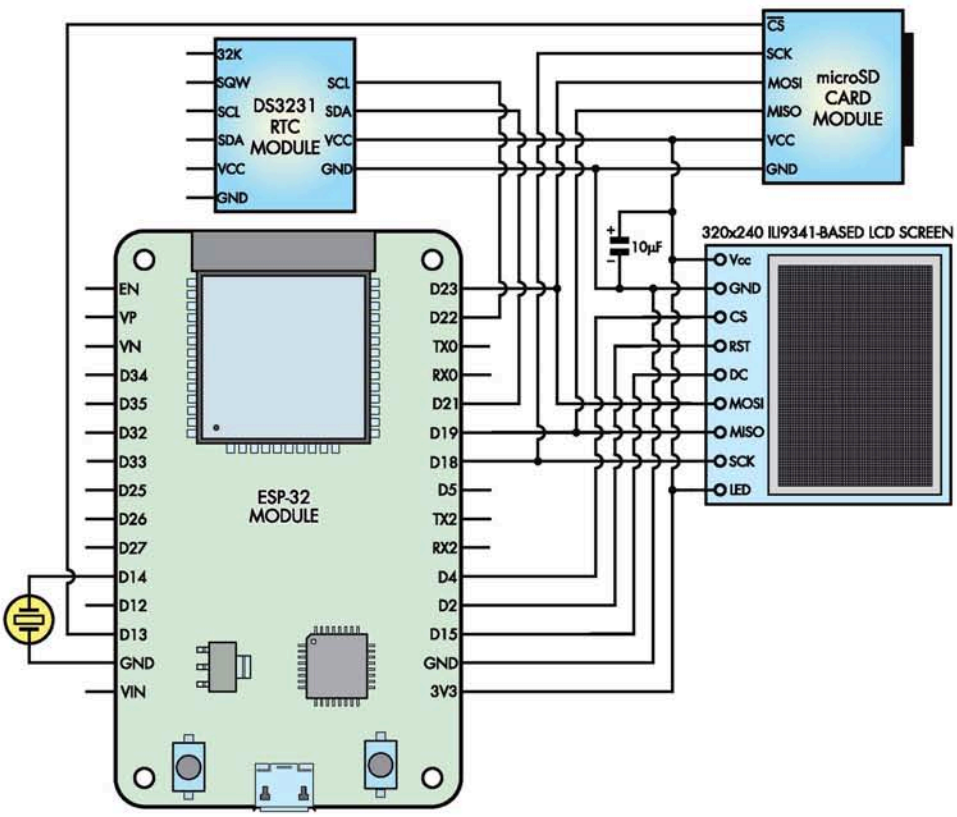
You will also need to enable support for the ESP32 board in the Arduino IDE before you can compile it. The instructions to do so are given here: siliconchip.com.au/link/aaiw

Once you've done that, you will need to load all the libraries (zipped) into the IDE before the sketch can be compiled and uploaded.

All the images for your slideshow need to be saved in BMP format in 320x240 pixel resolution with 24-bit RGB colour. They should be placed in the root directory of the SD card. You can use free software such as GIMP to convert images in other formats (such as JPG and PNG) to BMP.

Here is a YouTube videos showing the prototype in operation: https://youtu.be/Wpny5v6ZXoE

Bera Somnath,
Vindhyanagar, India. ($75)



ESP-32 BASED SLIDESHOW WITH ALARM CLOCK

TECH-UP YOUR NEXT ADVENTURE

KIT OUT YOUR VEHICLE WITH THE LATEST TECH

Jaycar Electronics

$329

PLUG 'N PLAY 5W UHF CB RADIO KIT DC-9012

Super compact and incorporates the latest Digital Signal Processing technology for maximum performance. Easy to install perfect for anyone who doesn't want to permanently install a UHF radio in their vehicle.

Includes CB radio (TX3100), high performance magnetic antenna, 12V cigarette lighter lead, 2.4m coax lead and a suction cup mount for the radio.

- Display flip function
- Dynamic volume control
- Programmable scan function

GME

$46.95

OBD-II HEADS UP DISPLAY

LA-9027

Displays relevant data (speed, water temp, battery voltage etc. on your windscreen

- Connects to OBDII port
- 3" multicolour LED display

Note: Check local regulations regarding installation position. Compliant installation requires position to be within fixed distances from dashboard for some locations.

LEARN ABOUT... OBD-II

On-Board Diagnostics II (OBD-II) is a standardised system for communicating with your car's Engine Control Unit computer.

With OBD-II you can monitor your car's speed, RPM, engine performance, temperature, battery voltage, fuel consumption and much more. It's easy, no special wiring or installation required.

OBD-II ENGINE CODE READER

PP-2145

Plugs into OBD-II port and transmits speed, RPM, fuel consumption, etc via Bluetooth® to your Smartphone.

Bluetooth

$69.95

SPEEDO CORRECTOR MODULE

AA-0376 **WAS $44.95**

Alters the speedometer signal up or down from 0% to 99% of the original signal.

- 12VDC
- 63(L) x 46(W) x 25(H)mm

NOW $39.95

SAVE $5

FROM $32.95

RESPONSE COAX CAR SPEAKERS

Ttitanium coated fibre woofers and silk dome tweeters for smooth high frequency response. 2 way. Sold as a pair.

4"	CS-2310	**$32.95**
5"	CS-2312	**$34.95**
6.5"	CS-2314	**$44.95**
6 X 9"	CS-2316	**$69.95**

NOW $69.95pr

SAVE $20

2" 720 LUMEN LED FLOODLIGHT SL-3938 WAS $89.95

Cost effective IP67 waterproof, dustproof and shockproof lights suited for 4WD or marine lighting applications. Mounting hardware included. Sold as a pair. 9 - 60V (10W).

- 12/24VDC

NOW $99

SAVE $30

STEELMATE CAR ALARM KIT LA-9003 WAS $129

Features voice feedback on alarm status and operational parameters such as open doors etc. Boot release button, manual override.

- 2 remotes included

See website for details.

$39.95

LED VOLTMETER 5-30VDC WITH BAR GRAPH QP-5589

Shows car voltage numerically and on a colour coded LED bar graph simultaneously.

- Panel mount and a surface mount "hood" supplied
- 6.3mm spade terminal connection

$39.95

4 PORT BACKSEAT USB CAR CHARGER MP-3690

Simultaneous 4-port USB charging. Works on 12/24VDC systems.

- 9.6A total output

Bluetooth

NOW $24.95

SAVE $15

BLUETOOTH® IN-CAR EARPIECE WITH USB CHARGER AR-3135 WAS $39.95

Povides hands free communication.

- Magnetic charging dock
- USB 2.1A and 1A charging ports

PS-2120

FROM $21.95

12V CAR POWER EXTENDERS

Plugs into cigarette power socket and neatly sits in your vehicle's cupholder.

DUAL USB SOCKETS PS-2120 **$21.95**

DUAL USB SOCKETS & PHONE CRADLE PS-2122 **$24.95**

VISIT OUR BRAND NEW STORE IN PORT ADELAIDE, SA

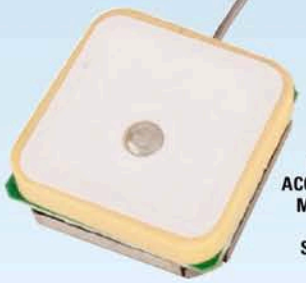
GPS RECEIVER MODULE XC-3712

NEW

A GPS receiver using the NEO6MV2 module, outputting NMEA data at 9600 baud. Excellent performance with a 50 channel receiver, 2m position accuracy and 0.1m/s speed accuracy.

- Ceramic antenna
- 4 Pin header for power and serial data
- 3.3V regulator on board
- Battery backed RAM

$49.95



BUILD A VEHICLE TRACKER OR LOGGER, OR EVEN USE THE ACCURATE SPEED MEASUREMENT TO CREATE A SPEEDOMETER.

SCREENS FOR YOUR CAR USING ARDUINO®

$15.95

128 X 128 LCD SCREEN MODULE XC-4629

Compact Colour TFT-LCD display supporting 16 bit colour at 128x128 pixels, and only needing six pins for full control.

- SPI interface
- 43(L) x 30(W) x 12(H)mm

$29.95

240 X 320 LCD TOUCH SCREEN XC-4630

Colour resistive touch LCD display shield. Piggy-backs straight onto your UNO or MEGA main board. Fast parallel interface. microSD card slot.

- Resistive touch interface
- 77(L) x 52(W) x 19(H)mm

BUILD YOUR OWN PARKING ASSISTANT

www.jaycar.com.au/ultrasonic-parking-assistant

Finished project.

$7.95

DUAL ULTRASONIC SENSOR MODULE XC-4442

The popular HC-SR04 ultrasonic distance module provides an easy way for your DuinoTECH to measure distances up to 4.5m.

- Uses two digital pins
- 45(W) x 20(D) x 13(H)mm

FROM $49.95

REMOTE CONTROL RELAY BOARDS

Add remote control functions to your projects with these handy relay boards. Set to momentary or latching mode.

- 40m max transmission range
- 12VDC

2 CHANNEL LR-8855 **$49.95**
4 CHANNEL LR-8857 **$69.95**

$14.95 ea

UNIVERSAL LED FLASHER RELAYS

Specifically designed to work with replacement low current LED indicator lights which may "hyper flash" when used with your cars standard flasher relay.

- Silent operation
- 40(H) x 30(W) x 30(L)mm

2 PIN 10A SY-4016
3 PIN 20A SY-4018

FROM $12.95

RELAY MODULES

Control a motor backwards and forwards without speed contro. Plenty of power (up to 10A at 30VDC), but need a separate 12VDC power supply to operate the relays. Provide isolation between the Arduino circuit and switched circuit.

4 CHANNEL XC-4440 **$12.95**
8 CHANNEL XC-4418 **$19.95**

$12.95

MOTOR CONTROL MODULE XC-4472

Has 2 x 5V servo ports connected to the Arduino's high-resolution dedicated timer to ensure jitter-free operation. Control up to four DC motors or two stepper motors.

- 5V to16VDC
- 70(L) x 53(W) x 20(H)mm

$7.95

DC-DC STEPDOWN MODULE XC-4514

Accepts any voltage from 4.5-35VDC, and outputs any lower voltage from 3-34V. Use it to run your 5V Duinotech projects from a 6V, 9V or even 12V supply.

- 4.5-35V input voltage, 3-34V output voltage
- 2.5A maximum output current
- 49(L) x 26(W) x 12(H)mm

$19.95

DC-DC BOOST MODULE WITH DISPLAY XC-4609

Can be used to provide higher voltages for your project, such as running 5V Arduino projects from Lithium batteries.

- Maximum 2A input current without heatsinking
- Solder terminals
- 66(L) x 35(W) x 12(H)mm

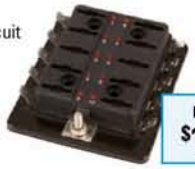
AUTO CIRCUIT PROTECTION

10-WAY BLADE FUSE BLOCKS

Perfect for automotive or marine applications. Removable protective cover and LED indicators for each fuse.

- Input: 100A max
- Output: 30A max per circuit

WITH LED INDICATORS SZ-2008 **$16.95**
WITH LED INDICATORS & WEATHERPROOF SZ-2001 **$19.95**



FROM $16.95

AUTOMOTIVE FUSE PACK SF-2142

120 standard size automotive fuses housed in a 6 compartment storage box. 20 x 5A, 10A, 15A, 20A, 25A & 30A fuses included.

$23.95

HEAVY DUTY PANEL MOUNT CIRCUIT BREAKERS

High quality units with multi-wire gauge inputs/outputs, perfect for high powered car audio, automotive or solar installations.

60A SZ-2081
120A SZ-2083
200A SZ-2085

$39.95 ea

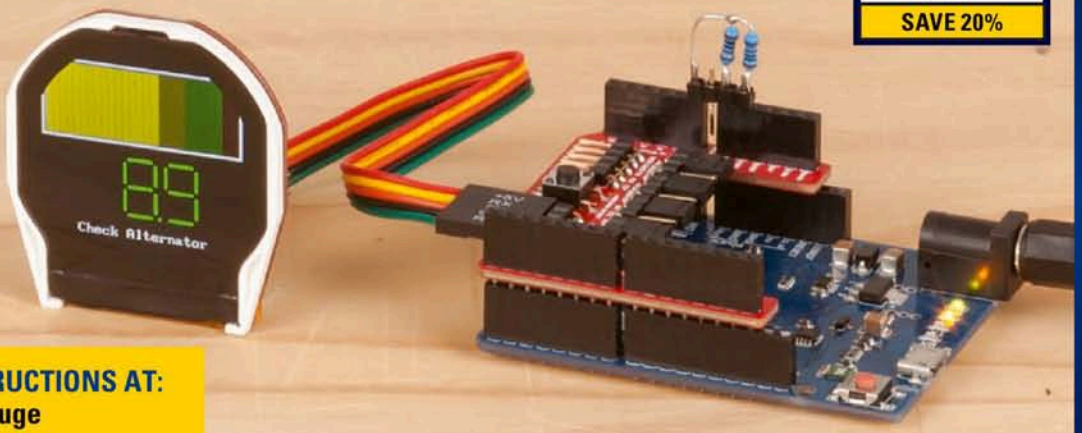
PROJECT OF THE MONTH

DUINOTECH MULTIFUNCTION VOLTAGE GAUGE

The XC-4284 Round LCD Module for Arduino® is an impressive piece of gear, capable of all manner of graphics, but especially suited as a round gauge. Here we'll show you how to interface the Round LCD Module to an Arduino® board for displaying system voltage and in a few different styles. Ultimately the round gauge just displays a numerical value, so any sort of numerical data (e.g. temperature, velocity etc) could be added to the gauge.

VALUED AT $101.85

NERD PERKS CLUB OFFER
BUY ALL FOR $79.95
SAVE 20%



SEE STEP-BY-STEP INSTRUCTIONS AT: jaycar.com.au/voltage-gauge

WHAT YOU NEED:

DUINOTECH LITE (LEONARDO)	XC-4430	**$29.95**
INTELLIGENT 1.3" ROUND LCD MODULE	XC-4284	**$69.95**
28 PIN HEADER TERMINAL STRIP	HM-3211	**$0.85**
10K OHM 0.5 WATT METAL FILM RESISTORS - PACK OF 8	RR-0596	**$0.55**
1K OHM 0.5 WATT METAL FILM RESISTORS - PACK OF 8	RR-0572	**$0.55**

SEE OTHER PROJECTS AT www.jaycar.com.au/arduino

$9.95

MICRO BLADE FUSES

SF-2146

Suit newer model cars. The pack contains one each of 5, 7.5, 25, 30A and two each of 10, 15, 20A.

- Pack of 10

$11.95 ea

FLEXIBLE DC POWER CABLE

Suitable for general purpose automotive and marine applications. 15A rated current.

- 10m roll

RED WH-3054
BLACK WH-3055
GREEN WH-3056

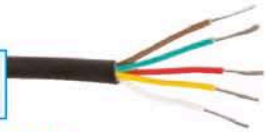
$14.50

ULTIMATE HEATSHRINK PACK

WH-5520

1 length each of 7 different colours in 7 different sizes ranging from 1.5mm dia to 20mm.

- Sizes: 1.5, 3, 5, 6, 10, 16 & 20mm



FROM $39.95

TRAILER CABLES

10m length sheathed in a tough black PVC jacket.

5 CORE WH-3091 **$39.95**
7 CORE WH-3090 **$44.95**

MAKE IT A PROJECT!

FROM $6.95

MERIT CONNECTORS

Commonly used in automotive power connections. Smaller in size, extremely rugged and provides higher reliability and current ratings.

15A UNFUSED PLUG PP-2090 **$6.95**
8A PLUG WITH CIGARETTE LIGHTER ADAPTOR PP-2094 **$6.95**
15A PANEL SOCKET WITH COVER PS-2092 **$9.95**
15A IN-LINE SOCKET WITH COVER PS-2096 **$6.95**

FROM $6.95

WATERPROOF DEUTSCH 2-WAY CONNECTOR SET

High quality connectors commonly used in automotive or marine applications. Perfect for connecting up sensors/lights in the bay due to their superior corrosion protection.

- 13A rated.

2-WAY PP-2150 **$6.95**
4-WAY PP-2149 **$8.95**
6-WAY PP-2148 **$9.95**

$19.95

12V TO 5VDC CONVERTER WIRING KIT MP-3675

Get rid of unsightly power cables floating around car dash that powers GPS, Dash Cam or mobile device.

- Micro USB Plug (Mini USB adaptor included)
- 2.5A continuous current
- Cable length 1.3m

$29.95

SOUND DEADENER

AX-3689

An easy single application solution for complete sound deadening and isolation that also offers thermal insulation.

- Combination of butyl and foam

CAR SECURITY

FROM $12.95

DOOR LOCK ACTUATORS

Used on passenger/driver doors. Durable, waterproof, dustproof and supplied with universal mounting hardware. Wiring not included. Input voltage: 9 - 16VDC.

SLAVE PASSENGER LR-8813 **$12.95**

MASTER DRIVER LR-8815 **$14.95**

$49.95

REMOTE CONTROLLED CAR CENTRAL LOCKING SYSTEM LR-8839

Upgrade to a remote keyless entry! Easy to install and comes with two remote key fobs.

- Includes master actuator, wiring and remotes

$89.95

4 DOOR REMOTE CONTROLLED CENTRAL LOCKING KIT WITH KILL SWITCH LR-8842

Lock and unlock your car doors from a distance without having to fumble around with keys. 9 - 16VDC.

- Frequency: 433.92MHz

CAR LIGHTING

FROM $9.95

INTERIOR LED RETROFIT KITS ZD-0585

Upgrade car/caravan/boat interior lighting with LED technology. Each kit consists of cool white LEDs with 3M adhesive foam backing. 12VDC. Universal T10/211/BA9S.

2.5W 260 LUMEN ZD-0585 **$9.95**

3.0W 310 LUMEN ZD-0587 **$12.95**

4.5W 450 LUMEN ZD-0589 **$14.95**

$12.95 ea

FESTOON LED GLOBES CANBUS COMPATIBLE

A range of 150 lumens ultra-bright white LED replacement "festoon" globes for car interior lights. 120° wide beam. 12VDC.

31MM ZD-0750

36MM ZD-0752

41MM ZD-0754

NOW $149

SAVE $20

H4 HI/LO LED POWERED HEADLAMP KIT SL-3524 WAS $169

Bright and efficient. Equipped with advanced Luxeon Z ES LEDs.

- Accurate LED position to ensure correct beam pattern
- 3800 lumens 40W
- 12/24V

RADIO + ANTENNA

ONLY $299

SAVE $49.95

5W IN-DASH UHF RADIO DC-1122

Compact size for under-dash mounting. Long transmission range up to 20km. Function buttons/controls are located on the microphone. Group scan, CTCSS & DCS,etc.

- 100 user programmable RX channels
- 12/24V

$249

UHF 5DBI FIBREGLASS ANTENNA WITH 5M CABLE DC-3078

Suitable for cars and trucks using UHF transceivers. Flexible spring base to absorb and deaden the vibrations associated with driving.

- 630mm long

$99.95

$18

RUBBER TOPMOUNT CAR ANTENNA AR-3260

Good for 4WDs etc. Small and flexible.

- 350mm long

CAR TEST & MEASUREMENT

$12.95

BATTERY, CHARGER AND ALTERNATOR TESTER QP-2258

Compact, lightweight, includes 600mm leads with croc clips, and inbuilt magnet to secure the unit while taking measurements. 12VDC.

$19.95

CAR BATTERY MONITOR QP-2220

Simply plug into the cigarette lighter socket and get an instant LED readout of the car's battery voltage.

- Works on 12/24V vehicles

$39.95

LED VOLTMETER & AMPMETER QP-5584

Monitor battery voltage and current draw. Supplied with a panel mount and a surface mount "hood". Connection via three 6.3mm spade terminals .

CAR ACCESSORIES

$16.95

CD-CASSETTE ADAPTOR AR-1760

Play your music from your media player through your car stereo cassette system.

- No power or batteries required
- Supplied with 1.1m lead & 3.5mm stereo plug

$19.95

SPRING CLAMP SUCTION MOUNT PHONE HOLDER HS-9039

Securely mounts to your windscreen with 360° rotation.

- Suits virtually any smartphone

$19.95

UNIVERSAL HEADREST TABLET BRACKET HS-9033

Fits just about any vehicle. Padded clamps to protect your device. 360° rotating ball-joint.

TECH TIP:

PORTABLE JUMP STARTER

Ever been stranded on the road with a flat car battery? An emergency portable car Jump Starter will help you avoid this frustrating situation.

Jaycar has an extensive range of Jump Starters, with some models so small they can fit in the palm of your hand, but still offer an impressive cranking current of 270A+ (plenty of power for kick starting most motor vehicles).

Higher power models allow you to kick start larger engines and enable you to use it multiple times before needing to recharge the unit.

Our MB-3736 Jump Starter also has a built in air compressor for inflating flat tyres too. The 12V/24V MB-3756 is ideal for your car (uses 12V) and your boat (uses 24V).

All the Jaycar range of Jump Starters are fitted with LED lighting (so you never have to work in the dark), and handy 5V USB outlets to charge mobile phones and other portable electronics devices.

Put a Jaycar Jump Starter in your glove box or the boot of your car or van, and you will never have to worry about a flat car battery again.

	MB-3760	MB-3757	MB-3758	MB-3736	MB-3756	MB-3752
VOLTAGE	12V	12V	12V	12V	12/24V	24V
CRANKING CURRENT	270A	300A	350A	400A	400/300A	400A
BATTERY TYPE	LiFePO4	Li-Po	Li-Po	SLA	Li-Ion	Li-Po
FEATURES	• LED Light • USB Out	• LED Light • USB Out	• LED Light • USB Out	• LED Light • USB Out • Air Compressor	• LED Light • USB Out	• LED Light • USB Out • 19V Laptop Supply

FITS IN THE GLOVEBOX!

$179

12V 300A LI-PO

MB-3757

Will crank an engine up to a 5L petrol, or 3L diesel.

- 300A continuous, 450A peak jump starting
- 2 x USB ports
- LED light
- 66(W) x 142(D) x 30(H)mm

FITS IN THE GLOVEBOX!

$279

12V 350A LI-PO

MB-3758

Will crank an engine up to 7L petrol or 4L diesel.

- 350A continuous, 700A peak jump starting
- 2 x USB ports
- LED light
- 85(W) x 216(D) x 36(H)mm

$189

12V 400A SLA

WITH AIR COMPRESSOR MB-3736

Will crank an engine up to 6L petrol or 3L diesel.

- 400A continuous, 1100A peak jump starting
- 2 x USB ports
- LED light
- Built-in air compressor with tyre inflator
- 285(L) x 227(W) x 310(H)mm

FITS IN THE GLOVEBOX!

$119

12V 270A LIFEPO4

WITH BATT & ALTERNATOR TEST MB-3760

Equipped with a LiFePO4 battery, making it compact & lightweight but still powerful.

- 270A continuous, 400A peak jump starting
- 2 x USB ports
- LED light
- Reverse polarity and short circuit protection
- 185(L) x 100(D) x 50(H)mm

$349

12/24V 400A/300A LI-ION

MB-3756

Suitable for most 12V or 24V vehicles including bus, trucks, jet ski etc.

- 400A/300A continuous, 800A/600A peak jump starting
- USB port
- LED light
- Carry case included
- 240(W) x 210(H) x 58(D)mm

NOW $139

SAVE $20

24V 400A LI-PO

MB-3752 **WAS $159**

Will start a Large cruiser boat.

- 400A continuous, 800A peak jump starting
- USB port
- LED light
- 190(L) x 150(H) x 90(W)mm

FROM $3.50 pr

CAR BATTERY CLIPS

Colour coded handles. Sold as a pair.

15A 55MM LONG HM-3010 **$3.50**
30A 70MM LONG HM-3012 **$3.95**
50A 98MM LONG HM-3015 **$5.50**
200A 35MM LONG HM-3060 **$9.95**
400A 155MM LONG HM-3085 **$15.95**

$12.95

80A 6 GAUGE TWIN CORE POWER CABLE WH-3067

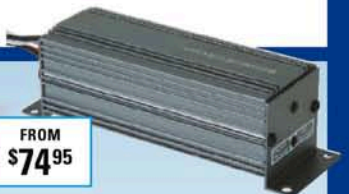
For high current applications. Red & black. PVC installation.

FROM $34.95

JUMPER LEADS WITH LEDS

Heavy duty pair of battery clamps with LED lights. Surge protected.

400A 3.0M LONG WH-6012 **$34.95**
700A 4.5M LONG WH-6014 **$69.95**



FROM $74.95

24VDC TO 12VDC CONVERTERS

Useful for running 12V devices from a 24V supply in a truck or bus. These converters have switchmode tecnology for light weight and compact design.

10A MP-3061 **$74.95**
20A MP-3063 **$119**

WORKBENCH ESSENTIALS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

$24.95

NOW $29.95 SAVE $10

NOW $59.95 SAVE $5

$79.95

$14.95

NOW $69.95 SAVE $10

1. STORAGE CASE HB-6302
- 4 trays: 233 x 122 x 32mm
- 13 compartments
- Top tray has a generous 265 x 160 x 65mm space
- 270(W) x 260(H) x 150(D)mm

2. AUTOMOTIVE DMM QM-1444
- CatIII 600V, 4000 count
- Inductive pickup for RPM measurement
- Dwell angle, duty cycle
- Data hold & relative function
- 146(H) x 66(W) x 42(D)mm

3. DIGITAL TACHOMETER QM-1448 **WAS $79.95**
- Measures up to 99,999 RPM
- Large LCD display, laser pointer, low battery indicator, memory recall etc.
- 5 Digit LCD display
- Supplied with carry case
- 72(W) x 160(H) x 37(D)mm

4. AUTOMOTIVE CRIMP TOOL WITH CONNECTORS TH-1848
- Excellent tool comes with 80 of the most popular automotive connectors
- Male & female bullets & spades
- Eye connectors
- Butt joiners

5. AUTOMOTIVE MULTI-FUNCTION CIRCUIT TESTER QM-1494 **WAS $64.95**
- Designed to test the electrical system of an automotive vehicle running on 12V or 24V
- Backlit LCD
- 240(L) x 78(H) x 40(W)mm

6. BENCH VICE TH-1766 **WAS $39.95**
- Made from hard-wearing diecast aluminium
- Vacuum base and ball joint clamp
- 75mm opening jaw
- 160mm tall (approx)

NON-CONTACT THERMOMETER WITH DUAL LASER TARGETING

QM-7221

Measure temperature from a safe distance.
- Laser pointing targeting
- Wide temperature range
- 12:1 distance to spot ratio
- 140(L) x90(W)x43(H)mm

$139

TYRE PRESSURE TESTER

QP-2287

Keep your tyre pressure in check.
- Measurement range: 5-100psi
- Large LCD readout
- LED light
- Tyre deflation monitoring

$29.95

$16.95

CORDLESS VOLTAGE TESTER

QP-2212

Quick and easy way to locate electrical faults without a bulky meter. Works on 3-28V circuits.
- Chrome metal construction
- Probe supplied

FROM $24.95

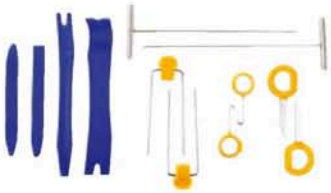
SELF-POWERED LED PANEL METERS

Simple 2 wire connection for voltage readout. Auto zero calibration and easy to read red LED display. Automatic polarity sensing. Cutout size 42 x 23mm.

VOLTMETER 8-30VDC QP-5586 **$24.95**

AMMETER 0-50ADC QP-5588 **$39.95**

$19.95



12 PIECE CAR AUDIO TOOL KIT TH-2339

Avoid leaving scars on your cars. This ABS pry tool kit is extremely useful for safely removing and installing car audio.

FROM $13.95

VERNIER CALIPERS

Calipers with LCD and etched vernier scale. 150mm range.

BUDGET TD-2081 **$13.95**

PROFESSIONAL. STAINLESS STEEL TD-2082 **$39.95**

$29.95

HEAVY DUTY STRIPPER, CUTTER & CRIMPER TH-1827

Strip all types of cable from AWG 10-24 gauge (0.13-6.0mm).

$39.95

300PC QC CRIMP CONNECTOR PACK

PT-4536

Contains bullet, ring, fork, spade and joiners in various sizes and colours.

$44.95

USB INSPECTION CAMERA

QC-3373

Inspect or locate objects in hard to reach places.
- Water resistant camera
- Adjustable LED lighting
- 1.5m flexible cable

EXCLUSIVE CLUB OFFERS:

FOR NERD PERKS CLUB MEMBERS

WE HAVE SPECIAL OFFERS EVERY MONTH. LOOK OUT FOR THESE TICKETS IN-STORE!
NOT A MEMBER? Visit www.jaycar.com.au/nerdperks

NERD PERKS CLUB OFFER

BUY 1 GET 2ND AT
HALF PRICE

SAVE 25%

KEVLAR SPEAKERS 4"-6.5"
Need two of the same speakers? Buy one, and grab a second speaker for half price.
e.g. CS-2400 Buy 1 for $79.95, get the second for $39.97 = $119.93 (Normally $159.90, Save $39.97)
4" CS-2400 **$79.95 EA**
5" CS-2401 **$99.95 EA**
6.5" CS-2402 **$119 EA**

NERD PERKS CLUB OFFER

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WIRELESS HEADPHONES*

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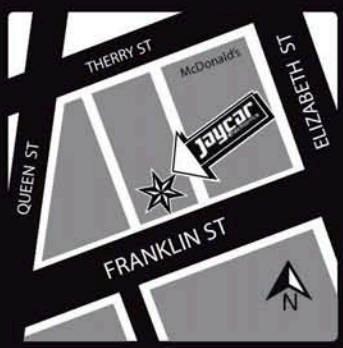

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from Catalogue Sale 24 February - 23 March, 2018.

PRODUCT SHOWCASE

Labjack T4 USB or Ethernet DAQ

Labjack have just released their new low cost USB or Ethernet T4 DAQ device for data logging, data acquisition, measurement and control applications.

The Labjack T4 comes with up to 12 analog inputs or 16 digital I/Os. There are four dedicated high voltage analog inputs (±10V, 12-bit resolution) as well as up to eight configurable low voltage analog inputs (0-2.5V, 12-bit resolution).

It also has two analog outputs (10-bit) and multiple digital counters/timers.

Labjack's Kipling software is available for basic configuration and testing. The LabJack T4 also comes with free DaqFactory Express Windows software that allows you to be quickly up and logging and graphing data.

Free code examples are available in C/C++, C#, Delphi, Java, LabVIEW, MATLAB, Python, VB.NET and more. The T4 is also capable of stand-alone operation by running Lua scripts and supports Modbus TCP protocol for industrial applications

Contact:
Ocean Controls
PO Box 2191, Seaford BC, VIC 3198
Tel: (03) 9782 5882
Website: www.oceancontrols.com.au

Shatter-proof mobile phone screens a step closer with ANU research

"Everyone knows how frustrating it is when you drop your mobile device and get a large crack in the screen," said Dr Le Losq from the ANU Research School of Earth Sciences.

New research at the ANU could lead to shatter-proof glass for mobile phone screens.

The researchers worked on a type of glass called alumino-silicate.They built on the long-standing collaborations from laboratories around the world.

Dr Le Losq said that the research, based on experiments and computer modelling, could be used to alter the structure of glass to improve resistance to fractures.

Contact:
ANU Research School Earth Sciences
Tel: (02) 6125 2381
email: charles.lelosq@anu.edu.au

Altronics auto rescue kit: save $30 in March

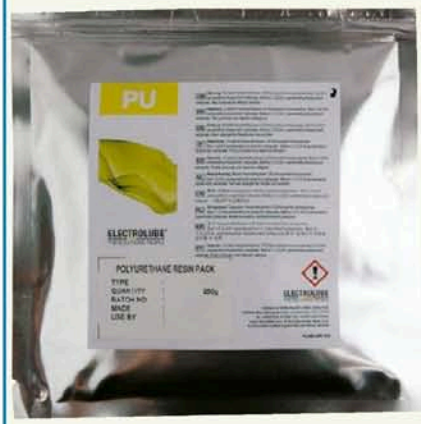
We've all seen those emergency jump starting kits. And mini air compressors to get you out of trouble. Now Altronics combines both with this nifty emergency pack!

It features a 16800mAh battery bank plus emergency compressor to top up tyres, provides 600A peak cranking output for cars with flat batteries,12/16/19V and USB output provided for powering devices.

Cat No is M-8198; special price in March is $139.00 - $30 off normal.

Contact:
Altronics Distributors (all stores)
Tel: (1300) 797 007
Website: www.altronics.com.au

Electrolube's new optically clear, flame retardant resin



Electrolube has launched a new encapsulation resin to meet the increasing demands from LED manufacturers for an optically clear, flame retardant resin.

The optically clear polyurethane resin, UR5641 is believed to be a market-first solution.

The two-part, semi-rigid resin cures to provide a flexible, protective and aesthetically pleasing covering over the luminaire elements and the aliphatic chemical nature of the cured resin is naturally resistant to the yellowing effects of UV light.

This makes it useful for a range of outdoor as well as indoor applications. UR5641 is also scratch resistant and offers high resistance to weather, acids and alkalis, water and mould growth.

UR5641 has a wide operating temperature of -40 to +120 °C and thermal conductivity of 0.20 W/m.K.

Importantly, UR5641 is flame-retardant and UL94 V-0 approved, making it eminently suitable for the protection of LED luminaires exposed to hazardous atmospheres, such as emergency lighting, or lighting intended for installation in ATEX rated/zoned environments.

Contact:
HK Wentworth
3/98 Old Pittwater Road, Brookvale NSW 2100
Tel: (02) 9938 1566
Website: www.electrolube.com.au

SERVICEMAN'S LOG

Squeezing an elephant through the eye of a needle

Dave Thompson*

A while back, I penned a column about some fun I had with some LED lamps in our range hood; in the editing process, this became a kind of electronics "whodunit" (a wotdunit?) and it appears some readers enjoyed the challenge.

The main thrust of that article was what an idiot I'd been for disassembling the whole thing only to discover the cause was a couple of easily-replaceable blown LEDs. Because my incompetence apparently knows no bounds, I have another potential head-scratcher for those interested in another challenge.

Sixteen months ago, when we moved to this house, we left behind a 100 megabit per second cable internet connection and inherited a slow, telephone wire-based ADSL pipe instead. This wouldn't do, so one the first things I did before we moved in was to get hold of our ISP and see what we could do about sprucing things up a bit internet-wise.

Like many customers, we weren't with this ISP by choice. Our original provider, a small start-up running out of Auckland was bought out by a bigger local player. They, in turn, were devoured by an even larger corporation from Australia.

This, as it turned out, was no bad thing, as this telco brought cable-based internet and related services to Christchurch and some other centres.

Whether any given street or road had the cable ring installed was determined by teams of marketing people literally walking all over the city and signing people up. If two people in any given street signed on for the new cable service, the cable was buried into that street.

Early-adopters like us enjoyed blazingly-fast (for that time) 100Mb/s connections until the ISP did what they all eventually do and oversold the system.

It was inevitable, as the likes of VoIP, internet TV and other web-based services gained popularity, that overall speeds declined. Eventually, there was little advantage of this cable connection over the ADSL, ADSL2 and VDSL technologies that were developing alongside it.

And then this ISP was gobbled up by an even larger global company, whose name always reminds me of that Star Wars character, Yoda. So through no choice of our own, they are now our service provider.

The main difference I've noticed is that when I called the smaller ISPs, I got through to a competent tech straight away and had problems sorted within minutes.

Then, as the companies got bigger, support call waiting times got longer and operators harder to cope with. I hate advising my clients that they have to call their ISP when internet problems arise because the experience is typically an exercise in frustration.

During our last move, I wanted to switch over to the then-brand-new fibre-optic internet that was available at our new home. But my alarm-monitoring company was reliant on the phone system (as so many are), and the ISP was adamant that we couldn't keep our copper phone lines if we wanted the fibre-optic internet connection.

That would mean we'd have to scupper alarm monitoring, which was a deal-breaker for me. I didn't want VoIP anyway, and besides, the ISP sold a so-called "naked" broadband fibre package right there on their website, which meant internet-only, yet when I suggested this option, I was told it wasn't possible and that the two systems could not be used side-by-side and that was that!

What transpired was a lot of wasted time on the phone to their support staff, who all claimed that it was standard practice that if a technician

Items Covered This Month

- Network woes
- FM car radio installation
- Dab Jetinox pump controller repair
- Chef Heritage oven repair

*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

came to connect the fibre, he would remove the copper connections at the same time. I tried to tell them these two installations were separate, but they wouldn't hear of it.

I had to really dig my toes in and fight my way up the chain until I finally found someone who would sign us up for fibre and allow us to keep the copper wire. This took at least half a dozen very long and often fraught phone conversations, just to order a fibre connection!

When the contracted tech finally came around to physically install the fibre, he couldn't understand why head office would be telling customers that the two systems couldn't live together.

He had no mandate to disconnect copper lines and said that like me, many others retained their old lines for legacy systems or simply to keep a separate, non-internet dependent phone line. Honestly, it shouldn't be this difficult!

Interestingly, when all this happened, they mentioned that this would be a 200Mb/s connection. However, when we moved in and I connected everything up, we would barely break 95Mb/s on the usual speed-test sites.

By this time, I was totally done talking to these guys, and since we had essentially what we'd had at our old address speed-wise, I didn't worry too much about it.

Confessions of a bandwidth junkie

Fast forward to December 5th this year. I saw an ad in one of our ISP's shopping-mall stores for a new connection plan called FibreX and this promised speeds of up to one gigabit per second, a truly marvellous prospect for those of us who consider 100Mb/s "barely adequate".

They boldly promised three months' credit if they couldn't connect us up in three days, so it sounded too good to be true.

Obviously, there was small print, which claimed the offer was only good for qualifying addresses; apparently FibreX was not available all over town, so when I got home, I hit their FibreX website and entered my address; the result trumpeted that we could get the service, so I put my prejudices aside and got on the phone.

The person at the other end assured me that we were all set, but they'd need to send me a new modem to replace our existing one, which was over a year old and so obviously now redundant. Fine by me, and so with a rosy feeling of accomplishment, I sat back and waited, anticipating how wonderful a one-gigabit connection must be.

A few days later, the modem arrived. However, as soon as I unpacked it, I saw a problem. It was a cable modem, designed for the same, older-style cable connection we'd had at our old address.

I promptly called the ISP and after the usual 30-minute wait told them I thought they'd sent the wrong modem. They assured me that was the right modem and that within a few days a technician would be out to put in the cable and away we would go.

By now mightily confused, I asked why a technician would have to come out when we already had a fibre connection and all that is required is a push-button speed increase at the ISP or exchange.

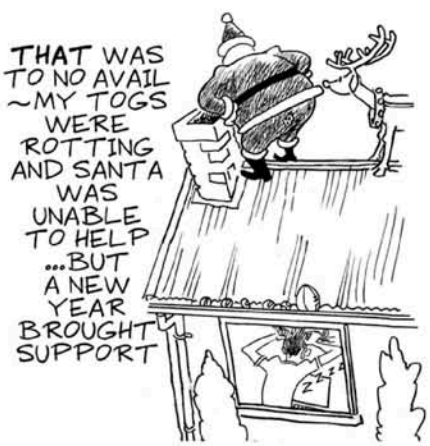
I was somewhat hampered by not knowing how these systems work beyond the connection to the house, but I assumed there was nothing required here for this speed increase to happen.

They insisted that a new cable had to be installed for the system to work and when I started asking questions, they kept bumping me around different departments until finally, after about two hours, I talked to someone who cottoned on that what had happened was that the person I talked to originally didn't double-check that we could actually get FibreX here, even though the system seemed to think we could.

We couldn't; FibreX is simply a hardware/speed upgrade to the old cable internet system, and it is still only available to customers in those streets it originally was installed in, and we didn't have it here. Excellent! What a complete waste of time; and I let them know in no uncertain terms what I thought about them and their "support".

To placate me, this operator told me about a super new product they were now implementing called FibreMax. This used our existing fibre connection and could also give us gigabit speeds, and that quietly this was even faster and cheaper than the FibreX system!

Somewhat mollified, I signed up on



the spot, with the operator claiming it would all go through on the nod within three days. All I had to do was wait.

Hurry up and wait

And so I waited; after a week of nothing happening speed-test-wise, I called them back (and by this time I was really disliking having to call them).

And once again, I had to start at the beginning and tell my story and then ask what was happening. Ah, the operator said, by the looks of it I was getting FibreX installed, and she could see the technician was due to come out and install it in a few days, so I'd just have to wait until then.

I couldn't believe what I was hearing. I very politely informed this person that I wasn't getting FibreX, I was supposed to be getting FibreMax, and that no technician was required.

This phone jockey didn't even know what FibreMax was, and after putting me on hold multiple times, she finally came back and transferred me to someone else, who again wanted the whole story and put me on hold for ages before returning to tell me there'd been a muck up in the provisioning, but now it was all sorted and it would be on within 24 hours.

It was also at this time I learned we were supposedly already enjoying a 200 megabit connection, as originally installed, so perhaps there was something wrong with our setup somewhere.

My modem was more than capable of these speeds and all my routers, switches and network cards are gigabit types so I just couldn't understand it.

My contact made some notes and suggested they'd sort the speed change first, then we'd see if there was something else holding our speed back. This sounded reasonable, so I left it at that and went back to waiting.

The following afternoon, I did another speed test and noticed that while our download speed hadn't changed, our upload speed had doubled to just under 90Mb/s, so something had definitely happened.

Still, our download speed stayed stubbornly shy of 100Mb/s and this whole thing was really starting to rot my togs.

Once more, I stepped into the breach and called the ISP. Another long hold later I was told I'd have to call the contracted telecommunications people who partnered with the ISP to provide this gigabit product.

My arguments about why I had to do this when I was paying them for this service fell on deaf ears, so all I could do was phone this other company.

At least the help desk technician who answered the phone after two rings knew his oats. While looking through the files, he could see two different orders had been put in for our address and the cancellation of FibreX and connection of FibreMax was causing all sorts of provisioning problems.

People were just pushing it back and forward to each company without actually doing anything. Unless I called, nothing would be done at all. Outstanding!

We were now about a week before Xmas and still, the speed test remained under 100Mb/s. Calls to the ISP and the contractor confirmed that everything was all-go at their respective ends, but nothing had happened here. They couldn't explain it. I tried another, different modem to no avail. So, dear reader, have you solved the diabolical mystery of who killed my bandwidth? Because at this stage, I still hadn't.

On the last workday before Christmas, I tried calling again. After yet more buck-passing from the ISP and assurances from the contractor that all was OK, I accepted that I'd have to leave it until after Christmas. And when I sat down and thought about it, there are people really struggling out there, or even having no Christmas at all, and here I am whining about not having faster Internet.

It's such a first-world problem and that really put things into perspective for me.

After Christmas, we braved one of the local malls and stopped in at another corner kiosk, figuring that we could at least talk to someone who had access to all the records. At this stage, all the guy we talked to could do was apologise for the events preceding all this. He also arranged to have their technical support guys call us back, the first time anyone had actually offered to do this.

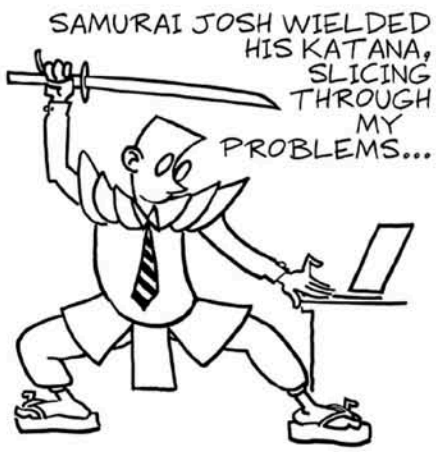
We accepted that the Wednesday after New Year's Day was likely the earliest time they could help us and left it at that. However, shortly after returning home, I got a call from the help desk to see if we could do something about it now. I was fine with that (it must have been a slow day on the help desk!) and sat down at my computer to assist him with setting up the remote login he'd use to have a look at our network.

After a few minutes, I could see him driving the computer and as we chatted on the phone, he looked at some of the settings and status information on the modem, pulling up a hidden screen that I'd not encountered on my travels through it. This page gave all the technical statistics of the network connections, protocols, packets and speeds up and down the pipe.

And within just a few minutes, "samurai" Josh, no doubt wielding his razor-sharp troubleshooting katana, had pinpointed the cause of our problems, leaving me very embarrassed and choking on a huge slice of humble pie.

You probably guessed the issue long ago; I didn't, and I call myself a tech. It turns out the "enhanced" Cat5e cables I'd used throughout the office when I set it up several years ago weren't that enhanced after all, and the routers were sensing this and throttling our local network speeds to 100Mb/s!

I simply had to change all the cables – those between the incoming fibre terminal and the new modem, and the computers and a couple of gigabit



switches through to the modem itself – to proper Cat6 cables, which in theory, would allow us to upgrade to 10 gigabits in future (when one gigabit becomes barely adequate...).

But for now, this has opened the floodgates and now our speed test has a much healthier 800Mb/s average.

The devil is in the details, and while they might have messed things up, I did too. Who would have thought a few measly cables would prove so troublesome...

Speaking from up high

F. W., of Moonee Valley, Vic, an experienced technician, recently set about installing a replacement radio in his grandson's new (second-hand) car, only to be stymied not once but twice. Here is how it went down...

My 18-year-old grandson just got his first car, a 2000 VT Holden Commodore, from a friend of the family. When he got it, the radio was missing, with a hole in the dashboard. Apparently, the original radio stopped working and was removed.

His mother bought him a new Pioneer radio and fitting it is where his father and I came in. I am a retired licensed aircraft engineer and car enthusiast and as my grandson has limited resources (ie, little money), the job was left to me.

I have fitted a lot of radios into cars and caravans over many years including the more modern ones with remotes, USB inputs and Bluetooth and have never had any problems. One thing I have found over the years is the difference between licensed aircraft engineers and some keen amateurs is that aircraft engineers work to a better standard. Anyway, I digress.

As the old radio had been removed and disposed of "because it didn't work" we were starting from an unknown base. First thing I figured out was that the original radio car loom plug had been cut off and a plug from some other radio had been "attached".

I put attached in quotes because the plug had been connected to the car loom using the best wire twisting techniques known to man and covered in some cases with insulation tape. So I decided to obtain an original VT Commodore radio loom plug and re-wire it properly to the car loom.

In the old days, one identified the 12V, earth and speaker wires on the car and joined the new radio wiring loom

USING THE BEST WIRE TWISTING TECHNIQUES KNOWN TO...?

to the car wiring loom, all of which took about 30 minutes. A permanent power supply was not required for earlier radios as they had no computers or memory to keep alive. A soldering iron, solder and some heat shrink tubing were the only tools required.

Then some smart people at a company called Aeropro decided to make things a bit easier by making adaptor looms and plugs to go between the vehicle wiring loom and the new radio. This speeds up the process dramatically and it only takes about 30 seconds.

I have installed several radios using Aeropro looms without any problems, so I decided to take the same approach this time. With the Aeropro looms fitted, I attached the aerial connector and we turned the ignition on.

In contrast to the radios of my youth which would immediately spring into life, the new ones have to be programmed first by carefully following the installation instructions in the book. Luckily, these steps are fairly straightforward.

The radio display started in a demo mode and then we completed the programming procedure. We selected a strong FM station and turned the volume up, but we were met with stony silence.

I removed the plug from the back of the radio and performed a series of checks which confirmed the following:

- we had 12V DC, both the switched (accessory) and permanent supplies.
- we had earth continuity to the car frame
- all speakers appeared OK, except for the passenger side front door speaker
- the antenna connection had continuity and no short to earth
- all the Aeropro leads had good continuity and the pins and sockets were all in good condition

I then hooked up all the plugs and looms and did a wiggle test with power on but still no sound, not even a bit of static.

As one speaker appeared to be faulty, we removed the interior panel (door card) to access the driver. We found the terminal block on the speaker (where the car wiring plug connects) had broken away from its mount and was literally floating around on the speaker cone wires.

As a consequence, it was most likely that the speaker cone wires were touching, causing a short circuit, or possibly they had dislodged from under the goop on the cone. The easiest solution was to get another speaker from the local wrecker's yard, which we duly did. We confirmed it operated on the bench and installed it.

We then re-installed the radio, programmed it and selected the same strong FM station but were once again greeted with more stony silence. As my grandson had to get to football and basketball practice, we called it a day.

The next morning, a web search confirmed that modern radios will typically refuse to work if there is a problem with any of the speakers, as they go into a protection mode. I assume this is intended to prevent damage to the amplifier section.

We had replaced the suspect speaker

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

so I didn't know what else could be wrong.

Then it hit me; I had not re-checked the speaker and wiring continuity after replacing the faulty driver. I once again checked all the speaker connections and once again, found a fault in the passenger-side front door speaker. That meant there must have been two problems in the same circuit!

Investigation showed a broken wire in the door opening. I repaired it and the radio then sprang into life. By the way, my grandson's football team won the Premiership, and he came runners-up in basketball, so we had wins all-round.

Pump controller repair story.

B. D., of Mount Hunter, NSW, had a problem with an irrigation pump controller that burnt out during use. The service agent was too busy to fix it but he had a go and managed to do it himself. His story is as follows...

I have a Dab Jetinox automatic pump which I use for irrigation on my small acreage. After a recent watering episode, I noticed that the pump had stopped after running for a couple of hours. On closer inspection, I saw that the pump warning light had come on and that pressing the reset button would not restart the pump.

I called the local agent and spoke to a technician who said that it was most likely a fault in the controller. The options were to replace the complete controller for around $200 or bypass it altogether and just operate the pump with the mains power switch for about $60 labour. The latter option would be OK as I was using it in that manner anyway.

These pumps have a pressure switch which stops the pump when the taps are turned off and a flow meter which stops the pump if it can't draw any liquid. I have the pump connected to quite an extensive PVC pipe network which won't hold pressure and causes the pump to cycle on and off fairly regularly if left on, so I switch it off unless I'm watering.

It is also unlikely to run dry as the suction line siphons from a dam. The controller also has some other functions to do with slow flows to reduce the amount of cycling. But I can get away without the controller, so next day I took it back to the agent to let him fix it.

I spoke to a sales assistant, as the technician was out in the field, and his response was less than enthusiastic.

He told me that they were snowed under because of all the dry weather we were having and they couldn't look at for a week or so. Well, I thought I may as well have a look at it myself as bypassing the controller should be pretty straightforward.

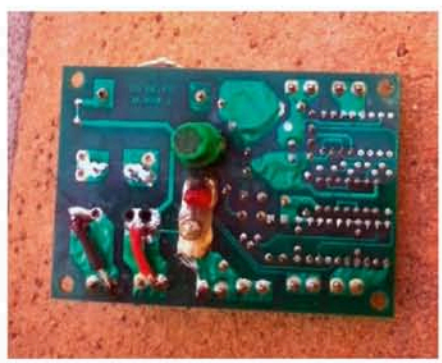
I took it home to my workshop. I thought I would just power it on before I start dismantling. To my surprise, the pump turned over. I quickly reconnected the water supply and tried again. Under load, the pump started, accompanied by fireworks from the controller and then it went dead.

I then started work on the controller which required me to use my set of special screwdriver bits to remove the cover. I noticed a circuit board covered in black soot, as well as a large capacitor and motor terminal. I photographed the board and made a sketch of the wiring connections.

I soon realised that the wires marked "nero" (black in Italian) and "maroon" (brown) were connected to the main relay and were the power wires for the pump. I disconnected these from the board and joined them together after insulating the join. I tried the pump and it ran without any problems and I used it to do a couple of hours of watering.

Since I had removed the circuit board from the controller, I thought I would have a look at it anyway. It consisted of a 240V relay which powers the pump, inputs for the pressure switch ("pressostato") and flow meter ("flussostato") and a logic chip controller. The relay coil is switched by 24V DC which is produced on the board.

I cleaned up the board and I could see on the underside that one of the 240V pins of the relay was surrounded by air as the solder had gone. I then removed the relay and saw the entire track on the top side of the board from this terminal to the spade connector had completely burnt away. It also took a 100kΩ resistor with it.



The circuit board from the controller after it had been cleaned.

This pump draws about 8A and this current was being carried by a top and bottom track about 1cm wide. Not surprising it failed eventually. I replaced the resistor and re-soldered the relay, this time including some reasonable size wires from the relay terminals to the spade lugs in parallel with the board tracks.

After re-fitting the repaired board to the controller, I tried the pump and it ran and cycled off and worked satisfactorily. Although I could have used it without the controller, I am glad it is fully operational as it could be used as a spare domestic water supply if required.

I am also glad that I didn't replace the controller as more than likely the replacement would have the same problem.

Not so hot by the seaside

B. C., of Dungog, NSW, recently did battle with a top-of-the-line oven, which contained not just one but two different faults just waiting to spoil dinner. Of course, he wasn't going to allow that to happen. Here is how he fixed it...

The day before an important family get-together, my friend's Chef Heritage gas oven and range went into a "limp" mode. Over the telephone, she said that this had happened before.

Usually, it would fix itself, but now she could not trust it anymore. As we were due to arrive there later that day, a request was made to bring my toolbox and soldering iron.

On arrival, I wasted no time and started my assessment of the fault. Fortunately, she still had the original Chef user's manual for the gas/electric range.

The original invoice was still enclosed, for $1178 plus $12 delivery charge. It was the flagship model made by Chef in 1984 and it had all the bells and whistles.

In addition to the four-burner gas hob and grill, there was also an electric party oven at the top and a fan forced gas oven below. An electronic clock/timer controlled both the grill and oven, and electronic spark ignition was used to automatically light all the gas burners. It stood at 1700 mm

high and was mostly made of enamelled steel.

An extra mechanism, in the centre of a double power outlet, was used to isolate the mains power for the gas range. After turning the electricity on, a buzzer made a series of beeps. Then a few seconds later, the clock/timer would stabilise and "HELP" was shown on the display.

After rotating the manual/auto switch to the set mode, I tried to use the "display set" up/down pushbuttons to set the current time. There was no response and the display was starting to flicker. The buzzer was now randomly beeping, no matter which position the rotary switch was set to.

There was no spark ignition available when attempting to light the gas oven or any of the hobs. The gas oven fan would not run and the party oven would not turn on.

However, the gas oven light was still working! Using a handheld gas lighter, it was still possible to light all the gas burners. Well, at least that meant that the gas part of the range was still working.

I carefully manoeuvred the range out from the gap where it had been installed. The removal of a large sheet metal cover then allowed access to the wiring in the rear of the unit. All the neutral wiring was blue and the active wiring was orange, with the exception of one red wire (that went to the party oven thermostat).

I disconnected and removed the clock/timer module from behind the range and took it to a workbench in the garage. The module case split into two halves, revealing a couple of PCBs. One was a power control/linear power supply PCB and the other, a microprocessor/display PCB.

I started by testing the power supply electrolytic capacitors with an ESR meter. They were all above specification, especially the 10µF/63V electro next to the 7805 voltage regulator. There were also 470µF/25V and 1000µF/63V electros near the rectifier diodes. I replaced them all as a matter of course. Any suspect solder joints were resoldered.

I then turned my attention to the microprocessor/display PCB. There was one PCB pad (near the 8MHz quartz crystal) where only two of the three trimmed pigtails had taken solder properly. This joint was resoldered. Both the rotary selector switches were also spray cleaned with solvent.

I connected a suitable mains power lead (terminated with insulated spade terminals) to the A and N input terminals on the power supply board.

After initialisation, the display was stable and the buzzer only beeped briefly when changing modes. The time could be set and the clock ran correctly, even when switched back to manual mode.

It was now time to reassemble and re-fit this clock/timer module back into the range. The brackets and screws were refitted. All the leads were reconnected and the mains power switched on. Every function appeared to be working normally again, and the range was left to soak test.

Then disaster struck! During the evening meal preparation, the electric party oven refused to work. Hastily, a toaster oven was temporarily pressed into service.

After the meal was finished, I clocked on for the afternoon shift. Upon examination, the clock/timer appeared to be working in its various modes but it was not controlling the electric party oven.

There was no way of avoiding it; the module would have to be taken out again! On my way back out to the shed, I pondered, were there still some other dry solder joints?

Using a fluorescent desk lamp and some magnifiers, I found nothing obvious. It was time to bench test the outputs. There were two relays that basically controlled the two ovens; when the relay output (for the electric party oven) was checked, with a 100W lamp load, it did not light.

With the mains power turned off, a multimeter showed no continuity through the relay coil. As I re-soldered the coil pins, one fell over at an angle. When this relay was removed from the PCB, only three of the four pins were intact.

Under magnification, I could see that the fourth pin had corroded away close to where it entered the plastic case.

Now, where was I going to find a suitable relay at this time of the evening? It was a 12V DC SPST 10A type. I went out to the courtyard (behind the house), into the appliance graveyard.

There I found an early model Sharp convection/microwave oven. After removing its top cover, I found an interface PCB inside with relays. This was removed and taken back to the shed.

Amongst these, thankfully, there was a suitable relay. With some modifications, it was fitted in place of the original relay. Bench testing then showed that the lamp would light when this output was selected.

The clock/timer module was reassembled and taken back into the kitchen. The module was re-fitted back into the range and it was with a great sense of relief to find everything was back to normal.

After prolonged soak testing and with occasional on/off cycling of the mains power, it continued to play ball. Early the next morning, the sheet metal back cover was re-fitted and the Chef Heritage range was pushed back into place.

Later it was put through a workout as a baked dinner for six people was prepared. It was the best baked dinner I had eaten for a long time! SC

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Want your own wireless station? Build this

We've designed this low-power AM Radio Transmitter for the opposite ends of the age spectrum! First, it's every kid's dream to play disc jockey and transmit programs around the house or maybe even next door. And the second, (mainly for our older readers) to let you "listen in" to the programs of your choice on that vintage radio set that you've lovingly restored.

AM Radio Transmitter

By JIM ROWE & NICHOLAS VINEN

Why would you want a broadcast band AM transmitter with a power output so low that it can only be received within a radius of just a few metres?

Well, apart from wanting to keep it all legal, let's say you've just finished building a replica of a classic 1940s' era AM radio, which you're entering a club competition. Wouldn't it be great if you could tune it into an "authentic" old time radio program, to recreate the way it might have sounded back then?

With this little transmitter, you'll be able to do just that, by rebroadcasting historic radio programs like those available on CD from Screensound Australia or even downloaded from the internet (eg, www.archive.com). Or you could play some classic tunes that you happen to have on CD or in MP3 format.

Alternatively, you might want to play the music from your personal MP3 or CD player through your car radio when you're out driving – but the car radio lacks direct audio inputs. With this little transmitter, that's no problem.

In short, the whole idea of this project is to allow any line-level audio signal to modulate an RF carrier in the AM broadcast band so that it can be played through a nearby conventional AM radio.

The carrier frequency of the transmitter can be tuned over most of the broadcast band, ie, from 650kHz to about 1500kHz. This allows you to choose a frequency that's away from any of the broadcasting stations operating in your area, to ensure interference-free reception.

The audio quality from the transmitter's signal is very close to that of the program material you feed into it because it uses a special balanced modulator IC.

There's also a modulation level control, so you can easily adjust the transmitter for the best balance between audio volume and minimum distortion.

But the best part is that the whole transmitter uses just a handful of parts and fits inside a standard UB3 sized plastic jiffy box. It's low in cost and easy to build, as all the parts fit on a small PCB. And there are no SMD components to worry about! You can run it from a plugpack power supply or a 9 or 12V battery, so safety isn't a problem, even for beginners.

Features & specifications

Transmission range:	~20cm (ferrite rod only), ~2-4m (with wire antenna)
Tuning range:	650-1500kHz (typical)
Supply voltage:	9-24V
Operating current:	9mA @ 12V DC
Adjustments:	tuning, fine tuning, modulation depth (volume), carrier balance

How it works

Although it's designed for very low output power, this transmitter uses the same basic principles as a high-power AM radio transmitter.

Fig.1 shows the details. It consists of an RF (radio frequency) oscillator,

a modulator and an RF output amplifier or "buffer".

The RF oscillator generates a sinewave of constant amplitude, with a frequency in the AM broadcast band. This provides the transmitter's RF carrier, which is the frequency you tune your AM radio to.

In most full-size AM transmitters, the RF oscillator uses a quartz crystal and is fixed in frequency, so the station concerned is always found at exactly the same place on your radio's tuning dial. However, in this case, the oscillator is tunable, so that you can set the transmitter's frequency to a part of the band that's unoccupied in your area, for clear reception.

The signal produced by the RF oscillator is fed into the modulator, which is the heart of the transmitter. As shown in Fig.1, this also receives the audio signal.

Stereo signals from the audio source are blended to mono via a simple mixing circuit. The resulting mono signal is then fed to the modulator via potentiometer which sets the modulation level.

Incidentally, if you wanted to transmit voice, you could use a microphone preamplifier to boost the tiny microphone output to a level that the transmitter can use (a microphone by itself would not be enough).

And if you wanted to do the whole "disc jockey" thing (voice AND music), you could use an audio mixer to handle both a microphone and a music source (for a suitable mixer, see siliconchip.com.au/Article/644).

The modulator uses the audio signal to vary the amplitude of the RF signal. the carrier).

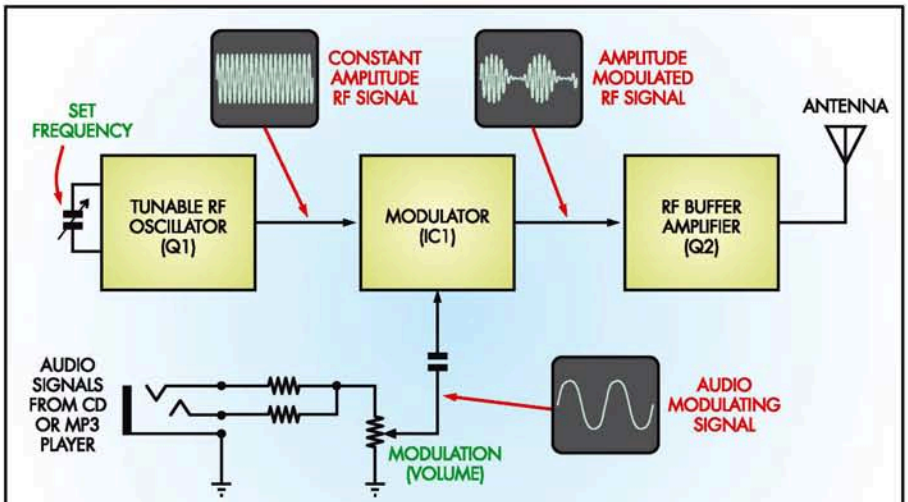


Fig.1: the block diagram for the AM Transmitter. A tunable RF oscillator sets the carrier frequency and this is amplitude-modulated by the audio signal. The modulator's output is then amplified and fed to an antenna.

When the audio signal swings positive, the amplitude of the carrier is increased and when it swings negative, the carrier's amplitude is reduced. In other words, the RF carrier is "amplitude-modulated". The waveforms in Fig.1 show the basic concept.

Amplitude modulation or AM is just one way of using an RF signal to carry audio or other kinds of information from one place to another.

The amplitude-modulated RF output from the modulator is very weak, so before it can be fed to our transmitting antenna (which is just a short length of wire), we have to increase its level by passing it through the third building block: the RF buffer amplifier.

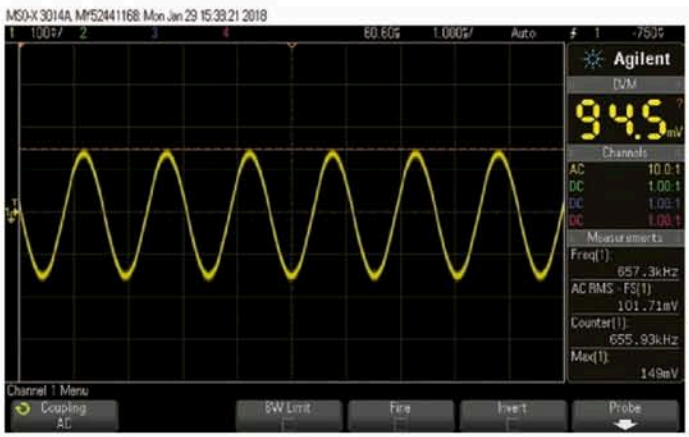
This stage amplifies the modulated RF signal to a level that's just high enough to cause weak radio signals to be radiated from the antenna.

Circuit details

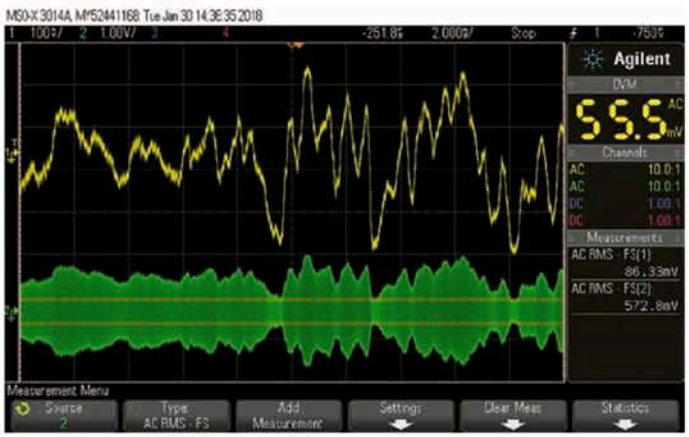
The full circuit of the AM Transmitter is shown in Fig.2. The RF oscillator is a Colpitts configuration, based around transistor Q1.

This uses the primary winding of RF transformer T1 as the inductive arm of its resonant circuit, along with fixed 470pF and 22pF capacitors and a miniature tuning capacitor (VC1). T1 is a local oscillator transformer from a low-cost AM receiver coil kit.

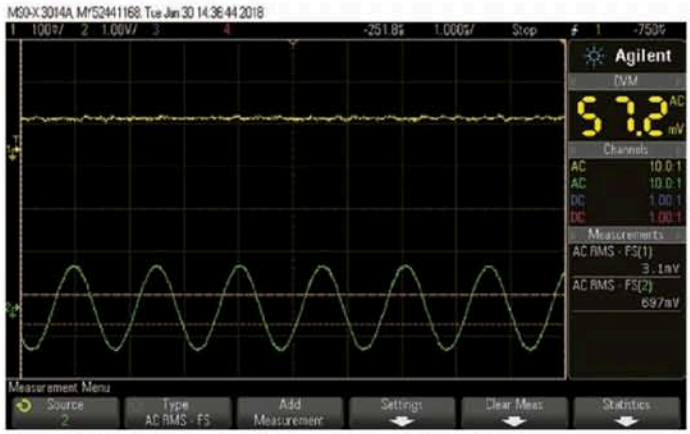
The output of the oscillator is taken from the secondary winding of T1. This is then fed through a 4.7nF DC blocking capacitor and a series 1kΩ resistor to one of the two carrier inputs (pin 10) of IC1, an MC1496 balanced modulator which has been designed



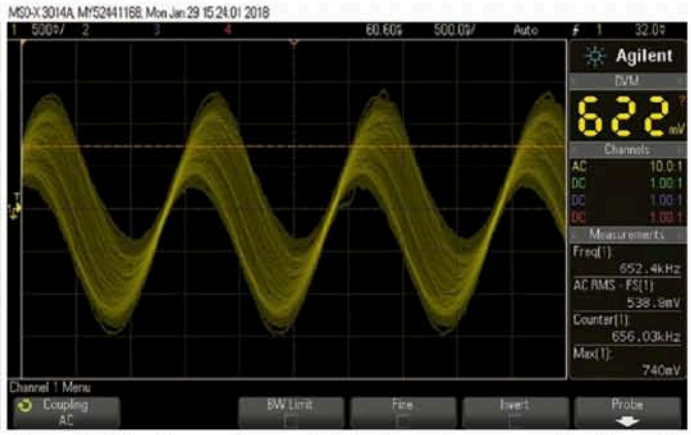
Scope1: this shows the oscillator waveform at the junction of T1 and the 4.7nF capacitor. The amplitude is around 100mV RMS, reduced from the 1V RMS at Q1's emitter due to T1's turns ratio. This is at the bottom end of the tuning range (around 650kHz) and the sinewave is quite clean.



Scope2: an audio signal that we fed into the transmitter is shown in yellow at the top while the AC voltage across the ferrite rod coil (L1) is shown below in green. Due to the long timebase, you can't see the carrier sinewave but you can see how its amplitude is being modulated by the audio signal.



Scope3: the same signal as in Scope2 but shown at a much faster timebase, so you can see the sinewave carrier waveform (in green). Over such a short period, the audio signal (in yellow) is not varying.



Scope4: this shows the modulated carrier across ferrite rod L1 but the scope was set up to overlay subsequent traces. The resultant "jitter" in the waveform is due to the audio modulation.

specifically for this kind of use.

The second carrier input of IC1, pin 8, is tied to ground as far as RF signals are concerned, via a 10nF capacitor.

However, the IC needs both its carrier inputs held at a DC bias level of about +6V and that's the purpose of the voltage divider network involving the 1.5kΩ, 560Ω and 1kΩ resistors between +12V and ground.

The 22µF capacitor filters out any low-frequency variations in this bias voltage.

The 1kΩ resistor between pins 8 and 10 ensures that both carrier inputs are biased at the +6V level. It also forms a voltage divider with the 1kΩ resistor from T1, to reduce the unmodulated carrier level at IC1's inputs to below 60mV RMS – the maximum level which can be applied to its carrier inputs for undistorted output.

You can see an example of the signal at the output side of T1 in the screen grab, Scope1.

IC1's audio modulating signal inputs are at pins 1 and 4 and these have to be biased lower than the carrier inputs, to about +4V DC.

The 560Ω and 1kΩ resistors form a divider between the +6V DC bias point and ground to derive the +4V DC bias voltage. This is applied to the two audio signal input pins (pins 1 & 4) via 1.5kΩ resistors.

The two 10kΩ resistors connected to trimpot VR1 reduce the bias voltage at these two inputs slightly but VR1 also allows the DC offset between these two pins to be adjusted over a small range.

This affects the minimum carrier modulation level and careful adjustment of VR1 allows for a minimum carrier signal feed-through with maximal negative swing of the input audio signal.

The stereo audio input signal is fed into the unit via jack socket CON2 and mixed together via two 10kΩ resistors to form a mono signal. This signal is then fed to modulation depth (volume) control VR2.

Two 10kΩ resistors have been connected between the audio inputs of CON2 and ground. These are used to provide suitable loads for your signal source.

In some cases, if you are using the headphone output of a CD/MP3 player, mobile phone etc, its output amplifier may not operate if the load impedance is too high. 10kΩ will be sufficient for many devices but if necessary, these two resistors can be reduced in value (eg, to 1kΩ).

Keeping It Legal

This AM transmitter has very low RF power output (a tiny fraction of a watt) and is specifically designed to have a range of no more than a few metres, thus keeping it legal.

Do not attempt to modify the circuit with the aim of increasing its power output or to increase its range by feeding its output into any form of gain antenna, because this would greatly increase the risk of interfering with the reception of licensed broadcasting stations.

It would also make you liable to prosecution by the broadcasting and spectrum management authorities and probable confiscation of your equipment as well.

As shown in Fig.2, the modulating signal from VR2 is fed to just one of the modulator's audio input pins – in this case, to pin 1 via a 4.7µF DC blocking capacitor. The second input (pin 4) is tied to ground via a 100µF capacitor, so the full audio (AC) voltage from VR2 is effectively applied between the two input pins.

The 1kΩ resistor connected between pins 2 & 3 of IC1 is used to set the internal gain of the modulator, while the 10kΩ resistor from pin 5 to +12V sets the IC's internal bias and operating current level.

Modulated carrier outputs

The modulated carrier outputs from IC1 appear at pins 6 & 12, which are both connected to the +12V rail via 3.3kΩ load resistors.

In this circuit, we only use the output from pin 12 and this drives the base of RF amplifier transistor Q2 via a 220pF capacitor. The transistor's base bias is supplied by the 2.2MΩ connected to the +12V supply

Q2 is connected as a common-emitter amplifier and its output is developed across the collector load formed by L1, a broadcast-band antenna coil wound on a small ferrite rod.

As well as forming Q2's collector load, L1 actually forms part of the transmitter's antenna, because the ferrite rod inevitably radiates some RF energy.

However, its very small size makes it a rather poor radiator, so an external wire antenna (about two metres long) is also connected to Q2's collector via a 10nF coupling capacitor.

This dual-antenna system gives the

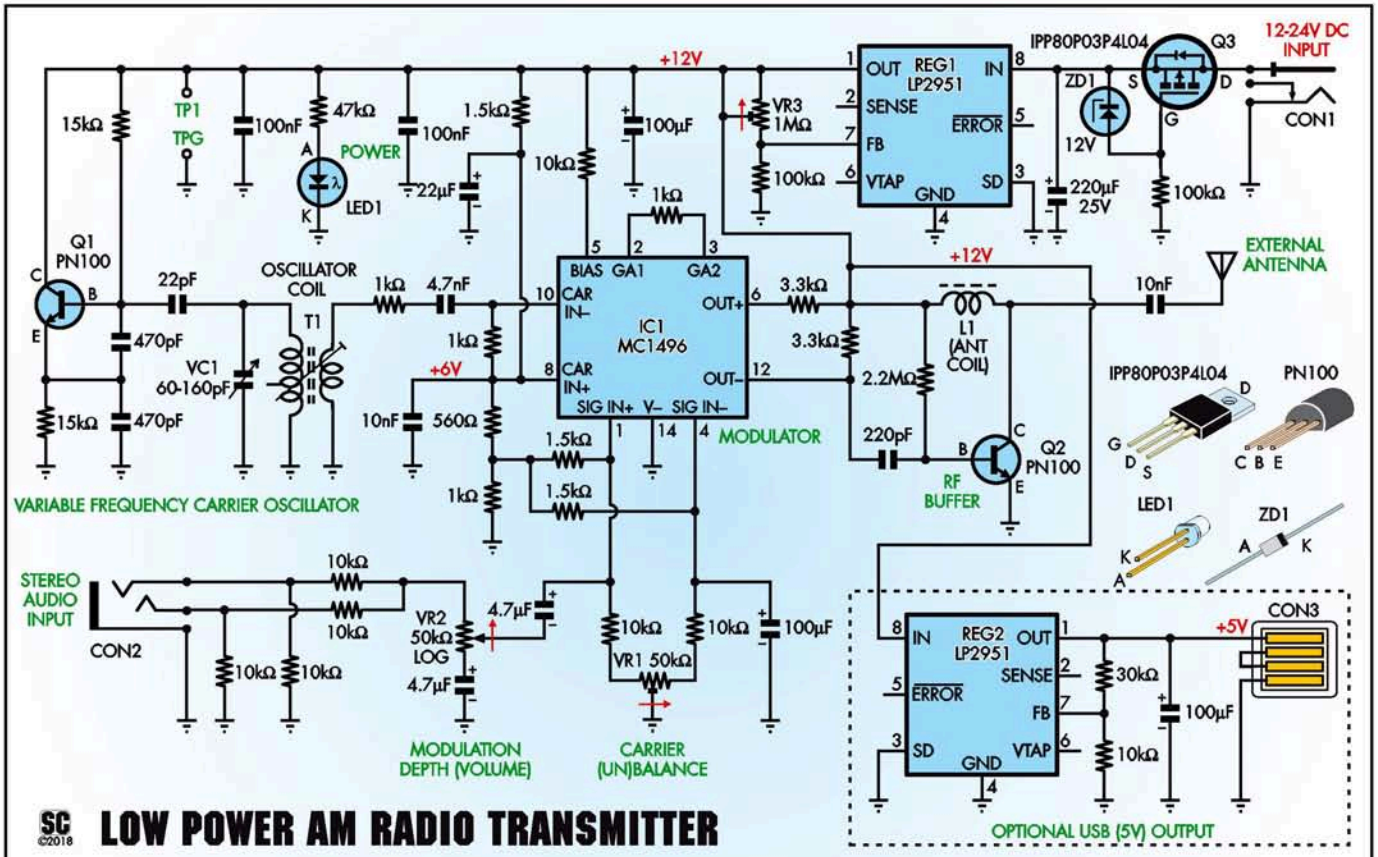


Fig.2: the circuit uses a Colpitts oscillator based on transistor Q1 to generate the carrier frequency which is then modulated by the audio signal fed into pin 1 of IC1 (MC1496). The modulated RF signal is then amplified by common-emitter amplifier stage Q2 and fed to the antenna. Potentiometer VR2 sets the modulation depth.

transmitter a range of about three or four metres, despite its very low RF power output.

You can see an example of the modulated carrier at the antenna terminal in screen grabs Scope2, Scope3 and Scope4.

Power supply and polarity protection

The circuit is powered by a regulated rail, shown as +12V in Fig.2 for simplicity, but it's actually set to around 11.7V. The reason for this is that we want to ensure a stable, regulated DC voltage even if a 12V supply is used. So we've arranged for 300mV of "headroom".

This not only suits regulated 12V DC mains supplies but also most 12V batteries and it has a negligible effect on the operation of the AM transmitter.

This requires the use of a low-dropout regulator and in this case, we are using a low-cost, micropower LP2951 adjustable regulator which can supply up to 100mA.

But normally this circuit only draws a few milliamps which means it has a "dropout voltage" under 200mV.

The input supply is connected via CON1 and Mosfet Q3 provides reverse polarity protection. If the supply is connected correctly, current flows through Mosfet Q3's parasitic diode and simultaneously, its gate is pulled to ground via the 100kΩ resistor, switching it on.

When on, the Mosfet channel "shorts out" the internal diode, resulting in almost no voltage drop across Q3. Hence, it does not raise the required supply voltage for regulation.

But if voltage is applied with the wrong polarity, the internal diode is reverse-biased and does not conduct. And with the gate pulled high, the Mosfet is switched off and so no current can flow through the channel.

The 12V zener diode between gate and source prevents damage to Q3 if a supply voltage beyond its +16/-5V gate-source rating is applied and the 100kΩ resistor limits the current through ZD1 in this condition.

The output voltage of REG1 is set to 11.7V by adjusting VR3. This forms a divider with the 100kΩ resistor across the output and controls what proportion of the output voltage is fed to feedback input pin 7. The regulator uses negative feedback to maintain this pin at a nominal +1.23V.

So we need a division ratio of 9.5 times (11.7V ÷ 1.23V) and this will be achieved when VR3 is adjusted for a resistance of 850kΩ [100kΩ x (9.5 – 1)]. Hence the use of a 1MΩ potentiometer. We need some extra adjustment range to account for variations in the internal 1.23V reference voltage.

Note that the 100kΩ/1MΩ divider resistor values are quite high and this is because REG1 has a minimum load specification of just 1µA and a quiescent current of around 70µA.

By keeping the resistor values high, we reduce the amount of current "wasted" in the feedback divider, which could otherwise swamp the quiescent current.

LED1 provides power-on indication. It's connected across the 12V supply in series with a 47kΩ current-limiting resistor (ie, the current through the LED is around 0.25mA).

By using a blue LED, we can get a

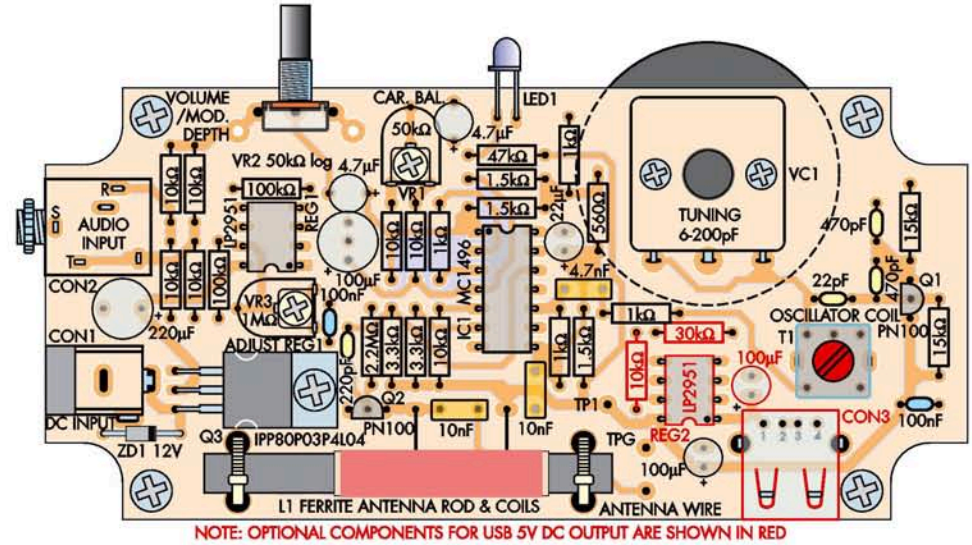
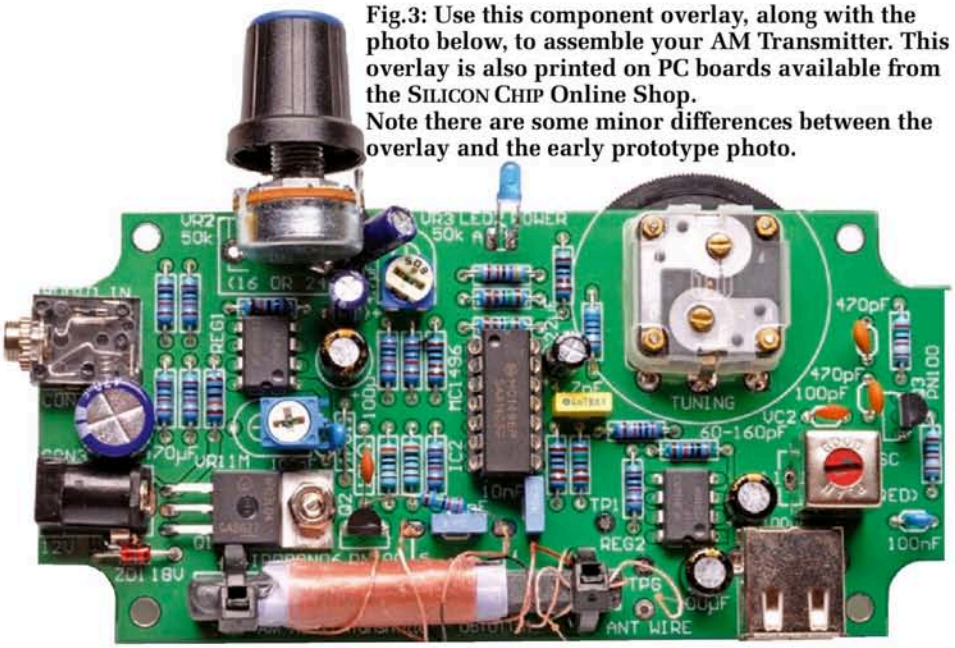


Fig.3: Use this component overlay, along with the photo below, to assemble your AM Transmitter. This overlay is also printed on PC boards available from the SILICON CHIP Online Shop.
Note there are some minor differences between the overlay and the early prototype photo.



sufficiently bright indicator without wasting too much current.

Optional USB supply for Bluetooth receiver

The PCB has provision for a second LP2951 regulator to provide a 5V, 100mA output. This is intended to power a Bluetooth audio receiver, so that you can wirelessly transmit audio from a mobile phone (or similar) to the AM Transmitter. The audio output of the Bluetooth receiver can be fed to CON2, so that the audio is then re-broadcast.

This only requires five extra components and is quite convenient since the Bluetooth receiver then simply plugs into the AM Transmitter and a separate power supply is not required.

These extra components are REG2, CON3, two resistors and a 100µF filter capacitor. Again, we've used an LP2951 since it has a low quiescent current. The resistors are chosen to give an output very close to 5V.

Construction

Construction is easy, with all the parts mounted on a small PCB measuring 122 x 57.5mm. This board has cutouts in each corner, so it fits inside a standard UB3 size jiffy box. The overlay diagram, Fig.3, shows where each component goes on the board. The extra components for the optional USB power socket are shown in RED.

Start by fitting the 26 small resistors. The resistor colour code table shows each value's colour coding bands. However, it can be difficult to distinguish certain colours even under the best conditions, so we strongly recommend that you check the value of each resistor with a digital multimeter (DMM) to verify it is correct before soldering.

Remember that you don't need to fit the 10kΩ and 30kΩ resistors nor the 100µF capacitor near REG2 if you are not building the unit with the USB power output option.

Follow with zener diode ZD1, ensuring that its cathode stripe is orientated as shown in Fig.2 before soldering. The ceramic and MKT capacitors can go in next. Like the resistors, these are not polarised and can again go either way around but be sure to fit the correct value in each position.

Solder IC1 in place now, with its pin 1 dot or notch as shown in Fig.2. We don't recommend that you use a socket. Having done that, fig REG1 in a similar manner – again, making sure it's orientated correctly. And if you're building it with the optional USB power supply, also fit REG2 in the location shown, then follow with the USB socket. Solder its two larger mounting pins first, then the four smaller signal pins.

Bend the leads of Mosfet Q3 so that it fits onto the board as shown, then attach its tab with an M3 screw and nut. Do the nut up tight and ensure the Mosfet is sitting straight before soldering and trimming the three leads.

Now fit jack socket CON2, ensuring it is sitting flat on the board and aligned with the edge before soldering its five pins. Proceed by installing trimpots VR1 and VR3; these are different values, 50kΩ for VR1 and 1MΩ for VR3 so don't get them mixed up. Mount the two small transistors next. They are the same type but you may need to crank their leads out with small pliers so they fit the patterns on the board before soldering.

The electrolytic capacitors can now be fitted, including the 4.7µF tantalum type. The aluminium types, in cylindrical cans, have a stripe on the negative side and a longer lead on the positive side, so ensure the positive lead goes through the pad marked "+" on the PCB, as shown in Fig.2. The tantalum type will have a "+" printed on its body and this should be lined up with the corresponding marking on the PCB.

One of the 100µF capacitors only needs to be fitted if you have already fitted REG2; its position is shown in Fig.4

You can now fit DC input connector CON1, again, making sure it's pushed down fully and aligned with the edge before using plenty of heat and solder to form good fillets between the three

flat tabs and the PCB pads.

The final capacitor to fit is tuning capacitor VC1. This fits on the top of the board, with its spindle stub shaft and three connection tabs passing down through matching holes in the board.

Turn the board over and attached the tuning cap body to the board using two of the M2.5 x 4mm screws supplied with it. Don't lose the third screw, though – you'll need it later to attach the disc knob to VC1's spindle. Now solder VC1's three pins to their corresponding board pads.

The oscillator coil T1 is next on the list. This is effectively polarised because there are three connection pins on one side of its base and only two on the other – be sure to orientate it correctly before pushing it all the way down onto the board. There are seven solder connections to make in all; five pin connections plus two for the can lugs.

You will need to cut the shaft of pot VR2 short, to around 10mm from the threaded ferrule, so that the knob doesn't stick out too far later. It's easier to do this before mounting VR2 although it can be done later if necessary. Having cut the shaft to length, solder VR2 in place.

Then fit LED1 with its body about 20mm above the board, making sure that the longer lead (anode) goes into the pad marked "A". Then bend its leads down through 90° about 14mm above the board, so that the LED faces away from the board and will later protrude through a matching hole in the side of the case later.

Antenna rod & coil

The final component to fit to the transmitter board is the antenna rod and coil assembly (L1). This is secured using two small cable ties, each of which loops around under the board through the pairs of 3mm holes provided for this purpose.

Do not replace the cable ties with wire or any other metal bands. A metal loop would form a "shorted turn" and this would absorb RF energy and seriously degrade the performance.

Unfortunately, making the coil's connections to the board can be a bit tricky. In most cases, there are four leads and it's not easy to work out which are the correct two to use – ie, the actual start and finish of the coil.

With the ferrite rod we used, the wires were marked with black, green, red and unmarked and the two we used were the black and unmarked wires. But other coils may use a different colour scheme.

In fact, the only reliable way to identify the start and finish leads is to check all lead combinations with an ohmmeter and go with the combination that gives the highest reading – typically around 11Ω.

Another little trap is that with many of these coils, the intermediate leads actually consist of two fine gauge insulated wires, twisted tightly and soldered together at their outer ends.

This means that if you decide to cut these leads short, they must be bared and soldered together again – otherwise, you'll find that the coil has become an open circuit between start and finish. And of course, the transmitter won't function very well with L1 open circuit!

A word of advice: if you do shorten any of the coil leads, it's a good idea to check the coil continuity with your multimeter before you solder the start and finish leads to the board.

Then it's time to fit the tuning disc (thumbwheel) to VC1's shaft and fasten it in place using the remaining M2.5 x 4mm screw.

A wire antenna is not strictly necessary as long as you can place ferrite rod L1 near the receiving radio's own ferrite rod or antenna (within 10cm or so). If you need a longer range, solder a 2m length of insulated hookup wire to the antenna terminal now.

The board assembly is then ready to attach to the box lid (used here as the transmitter's base). Before doing this, however, you may need to drill and cut the various holes in both the lid and the box itself, if you're building the project from scratch. The location, size and shape of each of the holes is shown in Fig.5.

The PCB assembly is secured to the lid using four M3 x 10mm tapped spacers and eight M3 x 6mm machine screws.

Once that's been done, it's time to check the transmitter's operation.

Checkout & adjustment

The first step is to set the supply voltage and for this, you will need a source of 12-20V DC power and a multimeter set to read volts.

Rotate VR3 fully anti-clockwise, connect the DMM between TP1 (red)

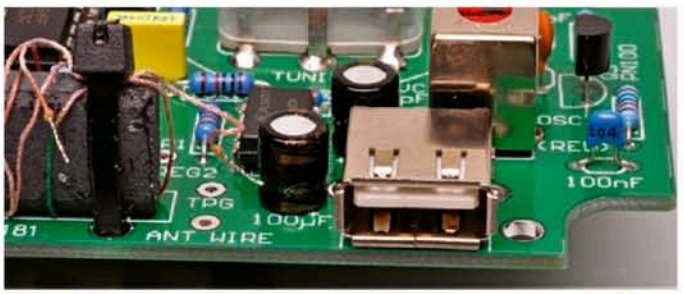
Vintage Australian Radio Programs On CD

If you'd like to rebroadcast genuine old time Aussie radio programs through your AM Transmitter, you should know that many of the programs are available from ScreenSound Australia (the National Screen and Sound Archive).

You can purchase CDs with classic "golden age of radio" programs, including quiz shows, serials like Dad & Dave and Mrs 'Obbs, comedies like The Bunkhouse Show and McCackie Mansion, and so on. For more information on what's available, visit the ScreenSound website at https://shop.nfsa.gov.au/

That's not the only source of music – as mentioned earlier, the US site www.archive.org has an enormous library covering just about everything ever recorded. And most countries have, or are working towards, archives of their own.

There are only two connection points on the PCB: sockets for the audio input (left) and 12V DC power (right).



This photo shows the optional USB (5V) power supply for Bluetooth receivers, etc. If you don't need it, leave them out.

and TPG (black) and apply power. LED1 should light up and you should get a reading of around 1.23V. Slowly rotate VR3 clockwise until you get a reading close to 11.7V.

If you have fitted the optional USB power output, now would be a good time to move the DMM's red lead to pin 1 of REG2 (the square pad at lower right) and verify that you get a reading between 4.75V and 5.5V. No adjustment should be necessary.

For the remaining steps, you will also need a reasonably sensitive AM radio receiver. Switch off, then follow this step-by-step adjustment procedure:

(1) Adjust the two fine tuning capacitors on VC1 so that the metal half-discs do not overlap.

(2) Switch the radio on and tune it to a convenient frequency in the lower section of the broadcast band, away from any of the local broadcasting stations (in Sydney, you can tune to about 820kHz).

(3) Turn the volume up (you'll just hear static at this stage) and position the radio near the transmitter, orientated so that its internal ferrite rod antenna is roughly parallel to the transmitter's ferrite rod.

(4) Turn the transmitter's tuning control (VC1) to one end of its range, set trimpot VR1 well away from its centre position (this is important) and set VR2 (modulation depth) to its midrange position.

(5) Turn the adjustment slug in T1 anticlockwise until it stops rotating (do this gently or you could crack the ferrite slug).

(6) Feed an audio signal into the transmitter by plugging the audio cable from your signal source into CON2. Start the source up and make sure it has a sufficiently loud (high amplitude) output signal.

(7) Apply power to the transmitter. Check that the voltage at pin 8 of IC1 is close to +6V; you can again use TPG as a ground reference. If this is correct, your transmitter is very likely to be working properly.

(8) Listen carefully to the radio while you turn the transmitter's tuning knob very slowly towards the other end of its range. At some point, you should start to hear the music from your MP3 or CD player, after which you should be able to tune the transmitter so that its signal is received at a good strength.

(9) If you have trouble getting the tuning exactly right, you can use the two small trimmers on VC1 and/or the adjustment slug in T1 to fine tune the oscillator but be gentle with T1's slug (remember that we already set it fully anti-clockwise) and note that this will shift the overall tuning range down slightly (ie, you may no longer be able to tune up to 1500kHz).

Troubleshooting

Can't find the signal? The first thing to do is to try tuning the transmitter back the other way but even more slowly and carefully than before. If this still doesn't bring success, try turning the adjustment slug in oscillator coil T1 anticlockwise another half-turn (or even a full turn if this later proves necessary).

This will shift the oscillator's tuning range up in frequency and should allow you to correctly adjust the transmitter when you tune VC1 over its range again.

Once you've found the signal and adjusted the transmitter's tuning control for the best reception, try turning

Parts list – AM Radio Transmitter

1 double-sided PCB, code 06101181, 122 x 57.5mm
1 UB3 Jiffy box (130 x 67 x 44mm)
1 ferrite rod, 55mm long, with broadcast band coil (L1)
1 mini RF oscillator coil in can with red slug (T1)
4 M3 x 10mm tapped spacers
9 M3 x 6mm machine screws
1 M3 hex nut
1 2.1mm or 2.5mm ID DC barrel socket, PCB-mount (CON1)
1 3.5mm switched stereo jack, PCB-mount (CON2)
1 small knob (to suit VR2)
2 100mm cable ties
1 2m length of insulated hookup wire (for antenna)

Semiconductors
1 MC1496 balanced modulator, DIP-14 (IC1) [Silicon Chip Online Shop Cat SC4533]
1 LP2951 adjustable micropower regulator, DIP-8 (REG1)
2 PN100 NPN transistors (Q1,Q2)
1 IPP80P03P4L04 P-channel Mosfet (Q3) [Silicon Chip Online Shop Cat SC4318]
1 3mm blue LED (LED1)
1 12V 1W zener diode (ZD1)

Capacitors
1 220µF 25V electrolytic
3 100µF 16V electrolytic
1 22µF 16V electrolytic
2 4.7µF 16V electrolytic or tantalum
2 100nF ceramic (disc or multi-layer)
2 10nF MKT
1 4.7nF MKT
2 470pF NP0/C0G ceramic
1 220pF NP0/C0G ceramic
1 22pF NP0/C0G ceramic
1 mini tuning capacitor 60-160pF, with thumbwheel and mounting screws (VC1)

Resistors (all 0.25W 1% metal film)
1 2.2MΩ 2 100kΩ 1 47kΩ 2 15kΩ 7 10kΩ 2 3.3kΩ 3 1.5kΩ 4 1kΩ 1 560Ω
1 50kΩ horizontal trimpot (VR1)
1 50kΩ 16mm PCB-mount logarithmic taper potentiometer (VR2)
1 1MΩ horizontal trimpot (VR3)

Optional extra parts for USB power output
1 LP2951 adjustable micropower regulator, DIP-8 (REG2)
1 horizontal PCB-mount type A USB socket (CON3)
1 100µF 16V electrolytic capacitor
1 30kΩ 0.25W 1% metal film resistor
1 10kΩ 0.25W 1% metal film resistor

Inside the MC1496 Double Balanced Mixer IC

The circuit opposite shows what's inside the MC1496 IC which forms the "heart" of the AM Transmitter. Compared to some other ICs which may have thousands or even millions of components, this one is dead simple!

It comprises eight transistors (nine if you count the diode, which is almost certainly a transistor with its collector and base shorted) and three resistors.

Given the relatively low operating frequency in this circuit (sub-1MHz), the transistors don't even need to be a particularly special type. So you could build a double-balanced mixer from discrete components fairly easily. But why do that?

The MC1496 basically consists of adouble differential amplifier (the top four transistors), a standard differential amplifier (the two below these) and a current mirror for biasing the different amplifiers (the bottom section).

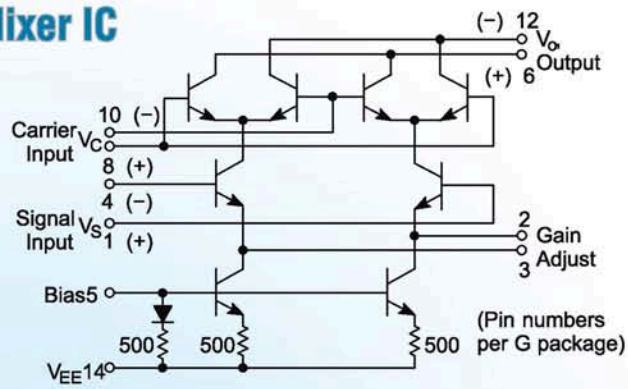
Starting at the bottom, an external current source is applied to pin 5 (Bias). This current flows through the diode and series 500Ω resistor to VEE (normally ground). This sets up a base bias voltage for the two transistors to the right. Since they also have 500Ω emitter resistors, and since their base-emitter voltage drop will be the same as the diode forward voltage, their collector currents will match the bias current.

The collector currents of these two transistors are ultimately sourced from the two outputs, at pin 6 (Vo+) and pin 12 (Vo-), shown at the top of the diagram. There is one current path from each output to each bias transistor. So say you supply 1mA to the Bias input.

That means that a total of 2mA will be drawn from Vo+ and Vo-, to supply the two 1mA current sinks at the bottom of the diagram. However, they will not necessarily be equal currents. For example, one could be 0.5mA and the other 1.5mA.

Notice that the upper two differential amplifiers are wired differently. In the left-hand differential amplifier, pin 8 (carrier +) drives the base of the transistor which controls current from pin 6 (V_o+) while in the right-hand differential amplifier, pin 8 (carrier +) drives the base of the transistor which controls current from pin 12 (V_o-).

So essentially, changes in the voltage of the + carrier input have the opposite effect on the differential output voltage compared to the – carrier input. And as you would expect, if you leave the signal inputs floating and simply apply a carrier, one output will simply duplicate the carrier signal while the other output will carry an inverted version of the same signal.



That just leaves us with the question of what the two extra transistors in the middle of the diagram do. These are connected to the signal inputs. The current through each transistor would be essentially fixed, because their emitters are connected to constant current sinks, except for the pin 2 & 3 connections, labelled "gain adjust".

A resistor is connected across these two pins and that allows current to flow from one side to another of the circuit, depending on which voltage is higher. And which voltage is higher depends on whether the voltage at pin 1 (signal input+) or pin 4 (signal input -) is higher, because these transistors are operating as emitter-followers.

Therefore, the differential input signal causes a differential voltage shift at the bottom of each of the differential amplifiers at top. And that shifts the current sharing between the two outputs, effectively controlling the gain of those upper pairs.

This has the effect of modulating the carrier signal which appears at the outputs, by an amount that depends on the resistor value between the gain adjust pins, because that controls how much current is shifted from one side to the other for a given signal input voltage swing.

The lower the resistor value, the greater the modulation (to a point).

And voila, we have generated a modulated RF carrier based on the applied signal.

up the transmitter's modulation control (VR2). This should make the reception even louder and clearer but if you turn the control up too far, the music will become distorted. Just back it off again until the distortion disappears.

Now is a good time to adjust trimpot VR1 for the best audio quality (maximum clarity).

We found that its optimum position was about halfway between the centre and one of the end positions of the rotor (on either side).

Don't set this trimpot (VR1) too close to its midway (centre) position, because this balances out the RF carrier altogether and gives double sideband (DSB) suppressed carrier modulation. And that gives quite a high distortion when you're using a normal AM receiver.

Once all the adjustments have been made, your AM Transmitter is working correctly and you're ready for the final assembly.

Final assembly

If your UB3 box has vertical PCB mounting ribs inside, you'll also have to cut some of these away.

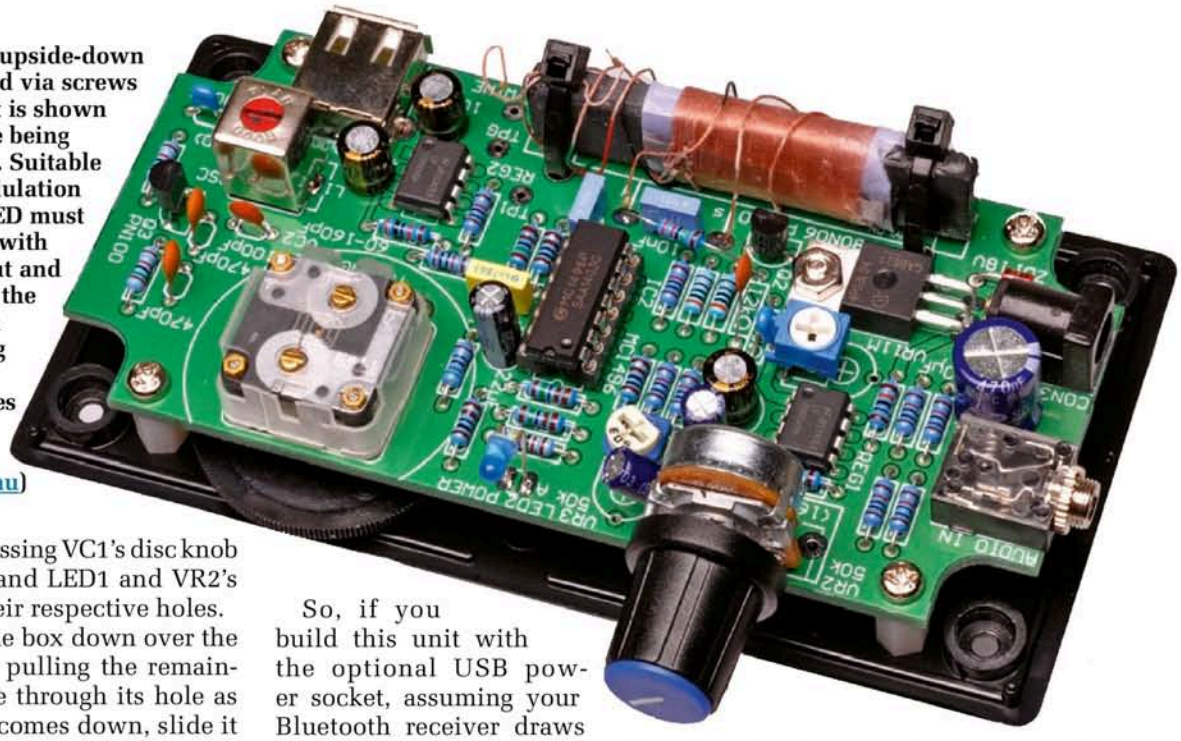
That's because the transmitter board assembly is a fairly tight fit inside the box and the ribs foul the ferrite rod and its coil.

The ribs to remove are mainly those at the rear side of the box, where they interfere with the ferrite rod. However, it's also a good idea to cut away any ribs on the end near the holes for CON1 and CON2 because these can make final assembly more difficult. You should also cut away any ribs on the front of the box, around the holes for LED1 and VR2, as this makes the final assembly even easier.

The ribs are easy to remove. The ABS material used in these boxes is fairly soft and can be cut away using a sharp hobby knife, small wood chisel or a rotary tool such as a Dremel.

Once the ribs are gone, remove the knob from modulation pot VR2 (if you have fitted it for the checkout) and unscrew the nut from VR2's ferrule.

You can now introduce the box to front of the lid/board assembly at a



The PCB mounts upside-down on the Jiffy box lid via screws and nuts – here it is shown in position before being fastened in place. Suitable holes for the modulation pot and power LED must be drilled (along with holes for the input and power sockets in the end; along with a slot for the tuning capacitor. (Drilling templates and panel art are available at siliconchip.com.au)

suitable angle, passing VC1's disc knob through its slot and LED1 and VR2's shaft through their respective holes.

Next, swing the box down over the board assembly, pulling the remaining antenna wire through its hole as you do so. As it comes down, slide it slightly towards the CON1/CON2 end, so that the ferrule of CON2 enters its clearance hole.

That done, you can fit the nut to VR2's threaded ferrule. Tighten it firmly and then refit the knob. Finally, turn the assembled box over and fit the four supplied self-tapping screws supplied to fasten everything together.

Connecting a Bluetooth receiver

A typical Bluetooth audio receiver is powered from a USB socket and has a 3.5mm stereo jack socket for the audio output.

Once you've paired your phone or tablet with it (see the supplied instructions) and your device is in range, it should connect automatically and any audio output will be received wirelessly and appear as a line-level signal at the output socket.

So, if you build this unit with the optional USB power socket, assuming your Bluetooth receiver draws no more than 100mA (most will be well under this), all you need to do is plug it into the power socket and connect a cable with 3.5mm stereo jack plugs at each end between the Bluetooth receiver audio output socket and the AM Transmitter's audio input socket.

You can verify the receiver is working by plugging a pair of headphones or earphones into its output socket and if so, you should have no trouble getting it to work with the AM Transmitter.

Just keep in mind that you will probably want to turn the Bluetooth and receiver volume controls right up and use the modulation depth control on the unit, to get the best audio quality.

Running it from a 9V battery

The AM Transmitter will operate from a 9V battery with slightly reduced output power and thus range. You just need to adjust VR3 to give around 8.5V at TP1.

The current consumption drops to around 7mA, giving more than 24 hours of runtime from a typical 9V alkaline battery.

Also, note our warning earlier about attempting to run from a higher voltage to achieve more output (and range). This would almost certainly make your transmitter illegal.

Tuning it to lower frequencies

It may be useful to modify the Transmitter to tune to around 450-455kHz, to allow you to inject a modulated test signal directly into a radio set.

This can be achieved by replacing the 22pF coupling capacitor with a 470pF ceramic capacitor. This should allow you to tune between 440kHz and 600kHz.

We do not suggest you add any extra capacitance across VC1 as it may prevent the oscillator from running. SC

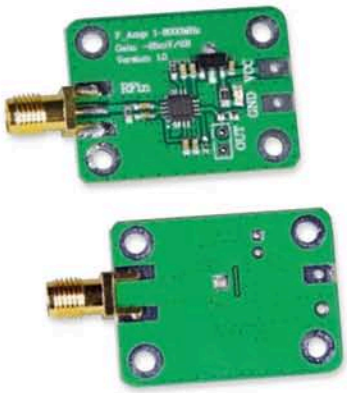
Resistor Colour Codes

	Qty.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	2.2MΩ	red red green brown	red red black yellow brown
☐	2	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	47kΩ	yellow violet orange brown	yellow violet black red brown
☐	0/1	30kΩ	orange black orange brown	orange black black red brown
☐	2	15kΩ	brown green orange brown	brown green black red brown
☐	7/8	10kΩ	brown black orange brown	brown black black red brown
☐	2	3.3kΩ	orange orange red brown	orange orange black brown brown
☐	3	1.5kΩ	brown green red brown	brown green black brown brown
☐	4	1kΩ	brown black red brown	brown black black brown brown
☐	1	560Ω	green blue brown brown	green blue black black brown

Small Capacitor Codes

	Qty.	Value	µF Code	EIA Code	IEC Code
☐	2	100nF	0.1µF	104	100n
☐	2	10nF	.01µF	103	10n
☐	1	4.7nF	.0047µF	472	4n7
☐	2	470pF	N/A	471 or 470	470p
☐	1	220pF	N/A	221 or 220	220p
☐	1	22pF	N/A	220 or 22	22p

Banggood's RF Detector



This nifty RF Detector module from Banggood can measure the power of RF signals from 1MHz to 8GHz, over a range of 60dB. It is on a tiny PCB measuring 33 x 24.5mm and has an SMA RF input connector attached to one end. It's based on the Analog Devices AD8318 chip, which is an enhanced version of the AD8307.

As a matter of interest, we used the Analog Devices AD8307 chip in the RF Level and Power Meter project of October 2008 (siliconchip.com.au/Article/1971) and also in the Arduino Multifunction Measuring Shield of April-May 2016 (siliconchip.com.au/Series/299).

Both the AD8318 and AD8307 are logarithmic amplifier/detectors which provide a DC output voltage proportional to the RF input power level. But the AD8318 has a much wider bandwidth of 1MHz to 8GHz, compared with the DC-500MHz range of the AD8307.

While the AD8307 has a range of just over 90dB, the AD8318 has a smaller dynamic range of about 60dB (necessary to get the improved frequency range).

Unlike the AD8307, which operates from a nominal supply voltage of 3V, the AD8318 is designed to operate from 5V. It also has a typical supply current of 68mA, compared with the 7.5mA drawn by the AD8307.

But perhaps the most important functional difference between the two devices is in terms of the output circuitry. The AD8307 has a current mirror in the output circuit which provides a positive slope to the DC output voltage. So the output voltage is directly proportional to the RF input level, with a slope of 25mV/dB.

In contrast, the AD8318 has a different output circuit designed to allow it to be used for power amplifier gain control. As a result, it provides an output voltage which is inversely proportional to the RF input, with a slope of -25mV/dB. Is this a problem? Not when you are going to use it in conjunction with an Arduino or other microcontroller.

Fig.1 shows a simplified version of the circuitry inside the AD8318. It has nine detector stages, interspersed with eight cascaded gain stages. The nine detector outputs are fed to an adder which drives a current-to-voltage converter to produce the output voltage, V_{OUT}.

The V-I (voltage-to-current) converter at upper right allows adjustment of the slope of V_{OUT} in measurement mode. For example, the output slope of -25mV/dB is achieved when the V_{SET} pin and the V_{OUT} pin are tied together.

Higher output slopes can be obtained by connecting a voltage divider between the V_{OUT} pin and ground, and feeding a fraction of V_{OUT} back to the V_{SET} pin. So if the voltage fed back to V_{SET} is $V_{OUT} \div 2$, this changes the output slope to -50mV/dB.

However, the output voltage is always in the range of 0.5-4.6V, so beyond -55mV/dB, the dynamic range will be reduced as the output at lower RF levels will be pegged at 4.6V.

Note that the AD8318 includes an internal temperature sensor as well as bias stabilisation circuitry for the cascaded gain stages so that changes

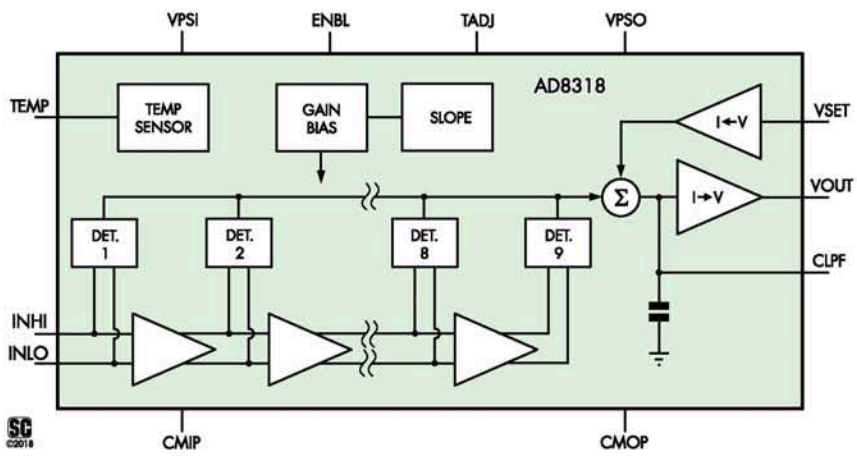
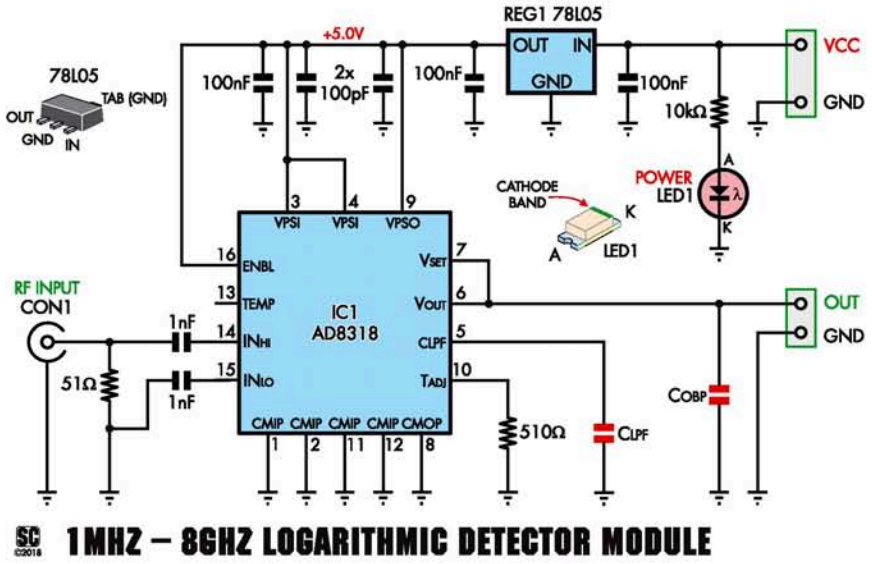


Fig.1: simplified block diagram of the AD8318 logarithmic detector/controller. It has nine detector stages interspersed with eight gain stages.



SC 1MHZ – 8GHZ LOGARITHMIC DETECTOR MODULE

Fig.2: circuit diagram of the log detector module. C_{LPF} and C_{OBP} are optional capacitors used to filter ripple from IC1's output. Suitable values are 1nF for C_{LPF} and 10nF for C_{OBP} with pads provided for mounting on the PCB.

in ambient temperature do not unduly affect accuracy.

All this is squeezed into a tiny 4 x 4mm 16-lead LFCSP (SMD) package; much smaller than the 8-pin SOIC/PDIP packages used for the aforementioned AD8307.

Now have a look at the circuit for the Banggood log detector module shown in Fig.2. Apart from the AD8318 chip itself (IC1), there is not much to it. The only other IC is REG1, a 78L05 regulator in a SOT-89 3-pin package with tab.

This provides a regulated 5V rail for IC1. But the 78L05 has a nominal dropout voltage of 2V, so the module needs a power supply (V_{CC}) of at least 7.5V.

As with many modules, there's one LED to indicate when power is applied. LED1 is connected directly between the V_{CC} input and ground with a 10kΩ series resistor.

CON1 is the RF input, an SMA edge-mount socket. This is terminated via a 51Ω resistor and then coupled to the IN_{HI} input (pin 14) of IC1 via a 1nF capacitor, with a second 1nF cap coupling the IN_{LO} pin of IC1 (pin 15) to ground.

As the input resistance of IC1 between pins 14 and 15 is close to 1200Ω, this gives the input circuit a low-frequency cutoff of around 300kHz. The effective input resistance at frequencies below about 100MHz is around 49Ω (51Ω || 1200Ω).

Pin 16 of IC1 is the enable input, which can be used to switch the device into a low-current standby mode if desired, by pulling it to ground. However, in the Banggood module, it's connected to the +5V line, so the chip always functions while the module is powered up.

But what's the purpose of that 510Ω resistor connected between pin 10 (T_{adj}) of IC1 and ground? It allows adjustment of the chip's internal temperature compensation, to optimise its operation at different frequencies.

A value of 510Ω apparently gives very close to optimum compensation at frequencies up to 2.2GHz, and also at 8GHz, while optimum operation at 3.6GHz and 5.8GHz can be achieved by changing R_{Tadj} to 51Ω or 1kΩ, respectively.

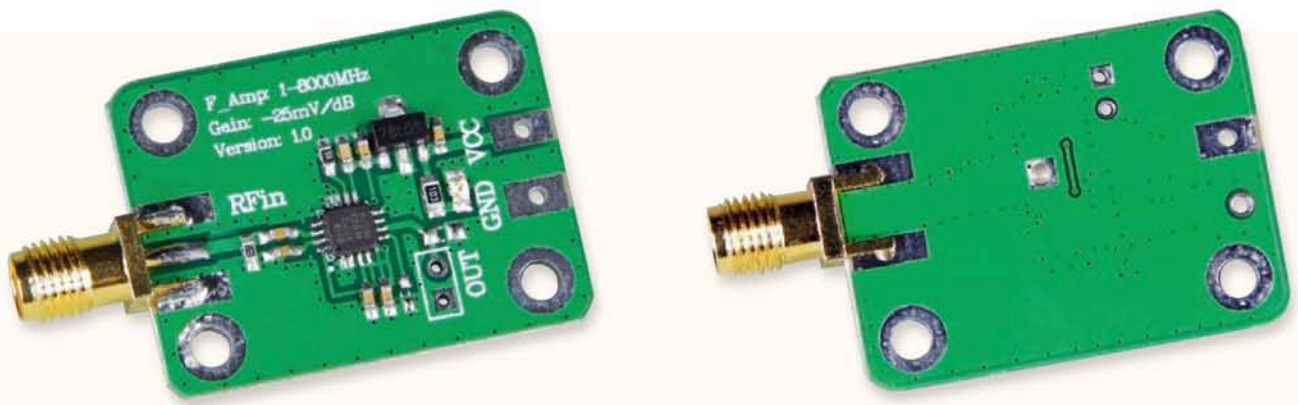
Even so, a value of 510Ω apparently gives acceptable performance over the whole range.

The two capacitors shown in red, C_{LPF} and C_{OBP}, are used for filtering any ripple in the output from IC1. If both capacitors are omitted, the nominal output video bandwidth of the AD8318 is around 45MHz, making it suitable for demodulating pulse signals.

But if you're using it purely for measuring unmodulated RF, this wide bandwidth can allow significant second-harmonic ripple to appear in the output for input signals below 22MHz.

Since this ripple can cause measurement jitter, the simplest way to reduce its effect is to add either C_{LPF} or C_{OBP}, or both. A suitable value for C_{LPF} is 1nF, while that for C_{OBP} is around 10nF and these values give an output bandwidth of around 100kHz.

By the way, neither of these capacitors are fitted to the module board (even though pads are provided for fitting them as 0603 SMD components)



Banggood's logarithmic RF Detector module detector module is based on the Analog Devices AD8318 chip. It has an RF bandwidth of 1MHz to 8GHz with a range of -65dBm to +5dBm and an input impedance of 50Ω. These photos are almost twice actual size.

which is why we've shown them in red in Fig.2.

Trying it out

To check out this module, I hooked it up to a suitable 9V DC power supply and connected its RF input up to a VHF/UHF signal generator.

Then I monitored its output using a 4.5-digit bench DMM while varying the RF input level over the range from +10dBm to -70dBm, for four different frequencies: 100MHz, 1GHz, 2GHz and 4GHz.

I wasn't able to go above 4GHz because that's the highest frequency my signal generator provides.

These measurement runs were used to plot the module's transfer characteristic at each of the four sample frequencies and the results are shown in Fig.3. The four plots are very close to linear between RF input levels from -5dBm down to -60dBm and only curve gently away at the upper and lower extremes.

Although the truly linear part of the module's transfer characteristic only covers about 55dB, the curved sections at each end give it a useful range of about 70dB as claimed in the data sheet.

The linear sections of all four plots are well within ±1dB of each other and have a slope of -24.33mV/dB; very close to the expected -25mV/dB.

Note that we've mentioned a 60dB range before, as this is the practical range over which you can expect to get an accurate result.

Connecting to an Arduino or Micromite

Interfacing this module to a micro is straightforward. Just feed the module with 7.5-9V DC and connect its Vout to either one of the micro's own ADC inputs directly, or to a higher-resolution ADC coupled to the micro via an SPI or I^2C interface.

Then it's just a matter of writing a firmware sketch or MMBasic program to read the analog Vout signal and convert it into an RF power level.

So this module should be suitable for use as the sensor section of a homebrew VHF/UHF level and power meter. You could even use it as an RF sensor head for our Arduino Multifunction Measuring Shield (MFM), although its negative-slope transfer characteristic would require some changes to the MFM's firmware sketch.

Other uses would be in an RSSI (received signal strength indicator) for UHF base station receivers and WLAN routers. In short, it seems to represent good value at around $16.50. SC

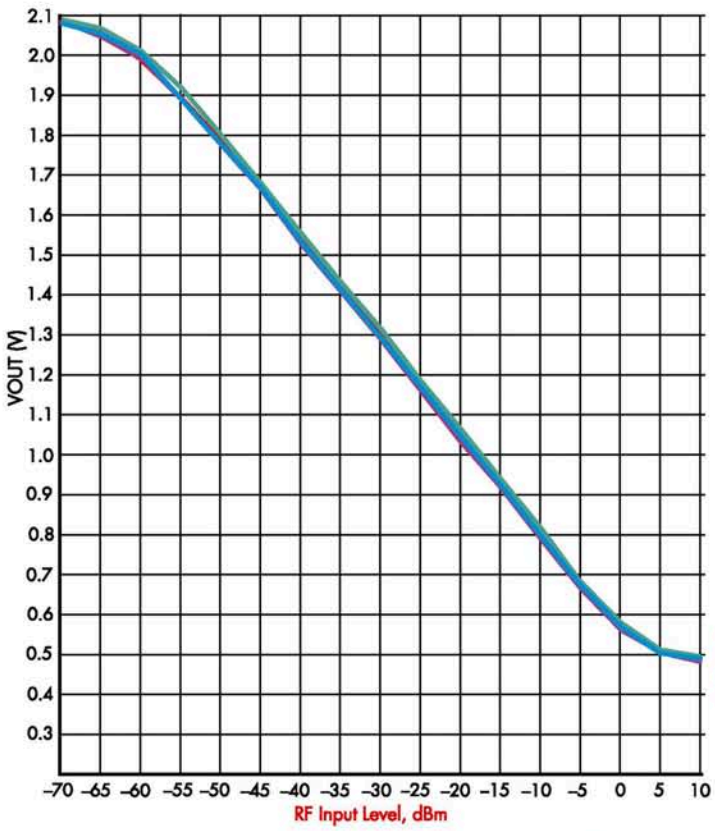


Fig.3: plot of the transfer characteristic for the AD8318 at four different input frequencies. Note the excellent linearity.

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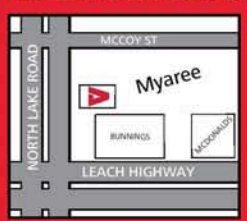

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View ANY program – even digital TV – on a Vintage TV Set with this

Analog TV audio/ video modulator

1950s' and 1960s' TVs are now old enough (and rare enough) to be regarded as collectable. But how do you enjoy them? You certainly can't use off-air signals – they're now all digital. And the output from a modern VCR or set-top box can be far from optimal for driving these old TV sets. This design will process that signal to provide optimum picture and sound quality.

Television first appeared in Australia in 1956 and was a great boon for the Australian electronics industry.

As with a vintage radio, you can restore a 1950/60s TV to working order and an increasing band of collectors and enthusiasts are doing just that.

But unlike AM radio (where analog and digital signals still happily coexist), vintage TVs can no longer be used as originally intended because of the shut-down of analog TV transmissions.

Of course, it is not only vintage TV collectors who may need a good signal for displaying on an old TV set.

Every time you see a TV series which might happen to show a working TV set of the era means that there is a need for an optimal signal.

Museums face this problem too and it is sometimes apparent that their display is far from optimum. After all, back in the days of black & white TV, people did not habitually watch poor quality pictures.

So what is the use of a beautifully restored TV if you can't watch anything on it?

The obvious approach is to use a commercial VHF TV RF modulator or the modulator in a VCR.

Either of these will accept a composite video signal and audio, which can come from a digital TV set-top box (allowing you to watch current TV channels), a digital media player or a DVD player.

By Ian Robertson

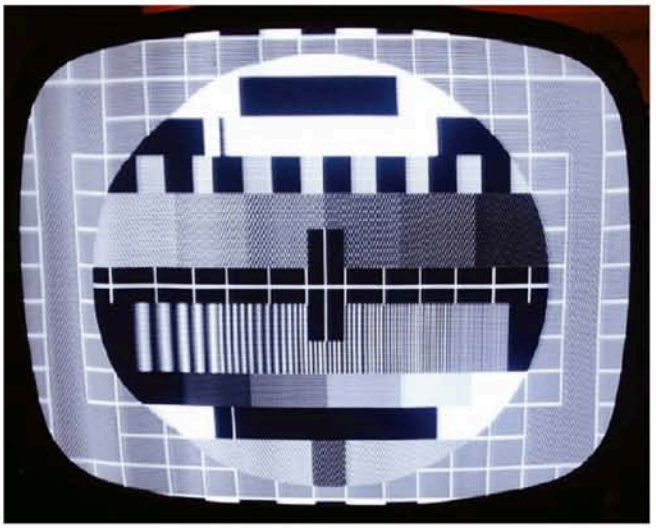
In most cases, provided your TV can tune to a channel your modulator can generate, you may get an acceptable picture and sound on your vintage TV this way. But chances are that the results will be disappointing.

Depending on the TV and the material you are playing, you may notice symptoms such as diagonal white lines and buzzing interference in the sound, spoiling your enjoyment of that classic movie or TV show. (See adjacent photo.)

Why does this happen?

Well, the short answer is that modern analog TV signals are different to those that were broadcast in the 1950s and 1960s.

The diagonal white lines often seen on older sets are retrace lines, which are normally hidden but can manifest themselves due to the VBI not being fully blanked. By the way, the blue cast on these screens is quite typical for sets of the day.



Here's a "test pattern" which displays a lot of information about the signal (in this case, after being processed by our new Video/Audio Modulator). The moiré pattern is caused by an interaction between screen and camera.

Firstly, in the late 1960s, in readiness for colour, the transmitted sound carrier power was quietly reduced from 25% of peak vision power to 10%.

The main effect at the time was that many older TVs became more critical to tune for good sound quality. That could be tricky because the tuning for best picture (with minimum snow) could result in poor sound.

The second change was the "discovery" in the mid-1970s of the Vertical Blanking Interval (VBI) in the TV signal.

The VBI is effectively the time that was included in the TV signal to allow the scanning beam in the receiver's CRT time to return from the bottom to the top of the screen (vertical retrace).

Prior to the mid-1970s, the VBI contained no information, just a black signal; actually, it was below the black signal level.

Then John Adams at Philips in the UK came up with the idea of transmitting text data in this otherwise wasted interval and Teletext was born.

Other uses soon appeared for the VBI. Amongst these were Vertical Interval Test Signal, Time Code and once home video recorders appeared, a number of copy protection schemes, notably Macrovision.

All these systems have three main attributes: They became embedded in the recorded video, they were virtually ubiquitous and the VBI portion of the signal was no longer below "black".

Why should this be a problem, since even vintage TVs have vertical retrace blanking circuits?

The answer is, it turns out to be almost impossible to fully blank peak white signals that occur in the VBI using available internal signals in the TV with passive circuits.

This is actually the rear panel of the Modulator – you'd normally bring all cables in here so it would be hidden.

Because such VBI manipulation hadn't been thought of, early TV designs simply didn't do it. Even some early colour TV designs were embarrassed by signals in the VBI and required field modifications.

VBI signals cause another problem. When fed to most RF modulators, the peak white excursions of the data in the VBI completely cut off the AM vision carrier.

This action "punches holes" in the FM sound carrier, causing an annoying buzz in the sound. You might remember this buzz from the days when you operated your TV through the VCR.

So what can be done about it?

You could modify the TV to bypass the entire RF section and feed vision and sound directly to the video and audio amplifiers.

When done properly, this can work very well but it does require specific modifications to each TV and arguably ruins the originality and authenticity of the set.

And since most vintage TVs used the AGC to provide contrast control, you will usually lose this control.

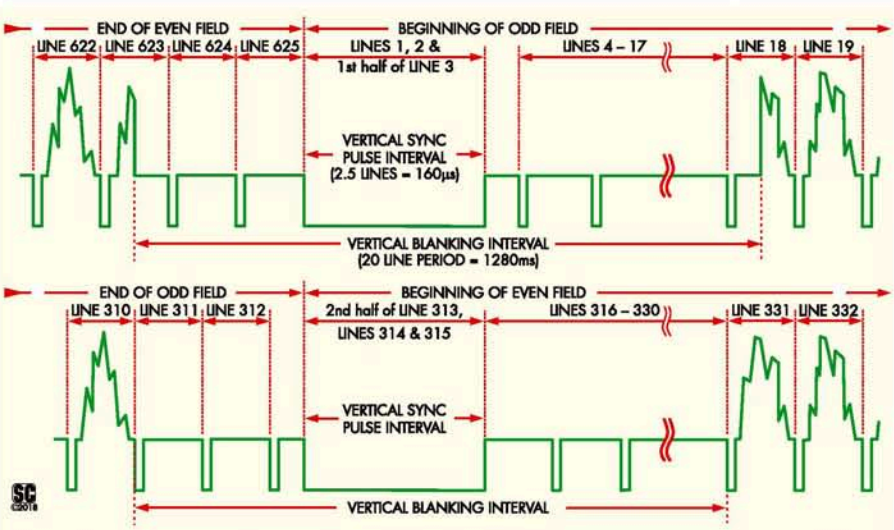


Fig.1: the structure of an analog video signal around the time of the vertical blanking interval (VBI), ie, the time between the transmission of each field (half of an interlaced image). This interval contains a negative sync pulse (much longer than the horizontal synchronisation pulses) plus a number of nominally blank lines. In many cases, they might not actually be blank and that can upset older TV sets.

What is really needed is a device that will convert modern video signals into a form suitable for any vintage TV.

To do so, we need to remove all signals during the VBI and return it to black, clip any peak white excursions above 1V peak, so they don't affect the sound, and generate a TV signal with a "B&W era" 25% sound carrier.

Then it should provide the best possible picture and sound quality. And ideally, it should be simple, inexpensive and easy to build!

Many possible design choices were evaluated. The video processor could have been implemented digitally but an analog solution was chosen because of the lower cost and complexity.

How it works

To reach the goals outlined just above, three main circuit sections are required: video processing, audio processing and RF modulation.

The video processing circuitry must detect the vertical synchronisation pulse and start a timer which lasts for the duration of the VBI (1.28ms) so that it can suppress any extraneous video signals during this time.

This is illustrated in Fig.1, which shows how the last two to three lines of each field are normally blank, containing only horizontal synchronisation pulses, which are negative excursions in the video signal, below the black level.

The vertical synchronisation pulse is essentially the same but much longer, lasting for 160µs, which is the time normally taken to scan 2.5 lines.

The remainder of the third line, plus lines 4 to 17 are blank and finally, the next field starts with line 18. So it's these blank lines which may contain unwanted signals that we need to suppress.

The rest of the time, during normal picture scanning, it needs to clamp the maximum signal level to the correct white level and by implication, it must also adjust the signal to achieve the correct black level.

Vintage TVs don't all display an accurate black level but it's needed anyway to ensure the minimum vision carrier level of 20% on peak white is observed, so that the sound is not affected.

Fig.2 shows the signal voltage during the scanning of one line. It starts with the horizontal blanking interval, during which time the CRT electron beam is being swept back to the start of the next line.

During this time, you can see there is a short pause (the front porch), followed by the short, negative horizontal synchronisation pulse, the back porch (which for colour signals, incorporates the PAL or NTSC colour burst), then the visible line interval, during which the video signal provides the brightness (luminance) information via its amplitude and, in the case of colour sets, the chrominance information via the phase information.

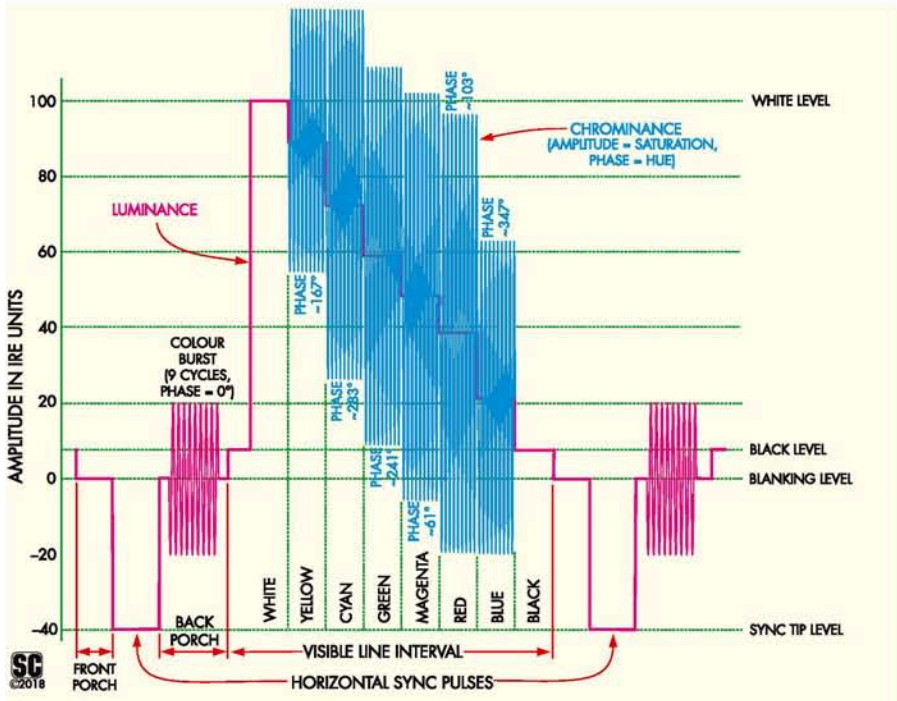


Fig.2: a PAL image contains 625 lines and each one is transmitted with a signal as shown here. The front porch and back porch provide a reference black level for the rest of the signal. The peak-to-peak amplitude, from the horizontal sync pulse to the white level, is normally 1V. Sometimes signals can exceed 1V; one of the jobs of the circuit described here is to prevent that as it can badly affect sound quality by blanking the audio FM carrier.

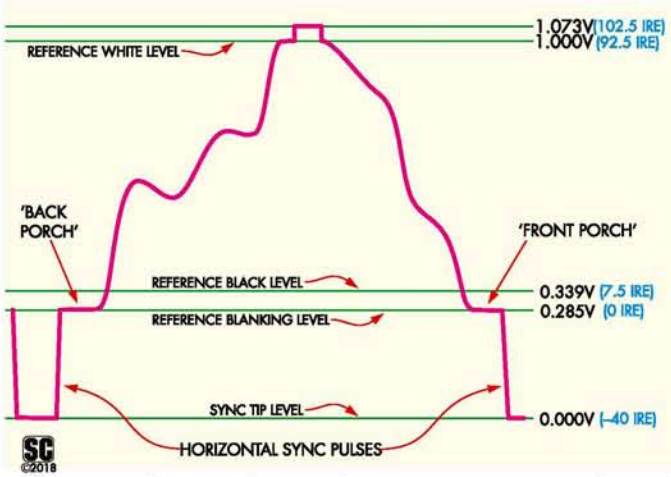


Fig.3: this waveform is a single video line showing the relationship between the various levels which can range between peak white (1.073V) and the sync tip level (0V).

The synchronisation pulses are nominally 285mV below the black level while the maximum white level should be about 715mV above the black level, giving a peak-to-peak voltage of around 1V.

The black level can be determined by monitoring the average signal level during either the front porch (just before the horizontal sync pulse) or the back porch (just after it). This design uses the back porch since it's easier to detect.

The overall design of the unit is shown in the block diagram, Fig.4. This shows how the vertical synchronisation pulse is detected by IC2 and then used to trigger pulse generator IC5a, which switches the video output between the version with the limited white level (clamped by diode D1) to the version with everything but the sync pulses removed (clamped by diode D2) during the VBI.

IC2 also detects the back porch period and this is fed to the circuit which normalises the black level so that the two clamps limit the video signal at the right levels.

The processed video and sound are then fed into audio/video modulator IC6. This includes an FM audio modulator with tunable carrier oscillator, RF oscillator for the video carrier and a double-balanced mixer. The two variable inductors, L1 and L2, allow the TV channel and FM sub-carrier to be tuned.

The sound is processed by applying an adjustable level of gain and then passing it through the correct pre-emphasis filter and this is then fed to the A/V modulator.

The RF modulated output passes through a low-pass filter and then to the RF output, which goes to the antenna input of the TV.

So now that we have discussed what processing must be done, let's look at the operation of the complete circuit, starting with the video processing section.

Circuit description

The full circuit is shown in Fig.5. The composite video and audio signals to be sent to the TV are fed into dual RCA socket CON1. A 75Ω termination resistor sets the load impedance correctly for the video signal, to eliminate reflections in the cable.

The video signal is then AC-coupled to non-inverting input pin 3 of IC1 via a 47µF capacitor and biased to 2.5V (half the 5V supply) by a pair of 10kΩ resistors.

IC1 is a video (wide-bandwidth) op amp which acts as a non-inverting buffer and also provides a gain of two, ie, doubling the signal amplitude.

The gain is set by the ratio of feedback resistors (1 + 4.7kΩ ÷ 4.7kΩ) and the 47µF capacitor at the bottom of this divider chain will charge up to the same bias level as applied to pin 3, so that the gain is not applied to the DC offset. That would cause output pin 1 of IC1 to be pegged to the +5V rail.

The signal at this output pin goes to two different sub-circuits; via a 100nF capacitor to IC2, the sync separator, and via a 4.7µF capacitor to emitter-follower buffer transistor Q1.

Let's look first at what happens to the signal buffered by Q1. As explained below, the base of Q1 is held at +1.5V during the back porch interval. This charges up the 4.7µF coupling capacitor.

Because the average voltage of the back porch is the black level, the black level of the signal at the base of Q1 becomes 1.5V.

Given the ~0.7V drop between its base and emitter, that sets the black level at its emitter to around 0.8V.

The signal at Q1's emitter passes through two 1kΩ resistors and then into inputs B0 and B1 of multiplexer IC3 (pins 1 & 2).

But there are also two dual schottky diodes, D1 and D2, connected to these pins. They are wired in parallel, so that they act like a single diode with a higher current rating and lower forward voltage.

Let's consider the signal at input pin

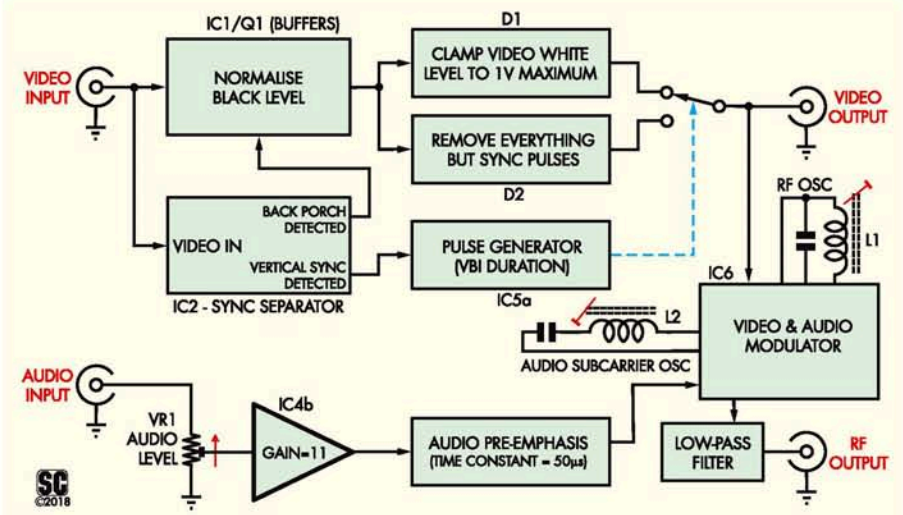
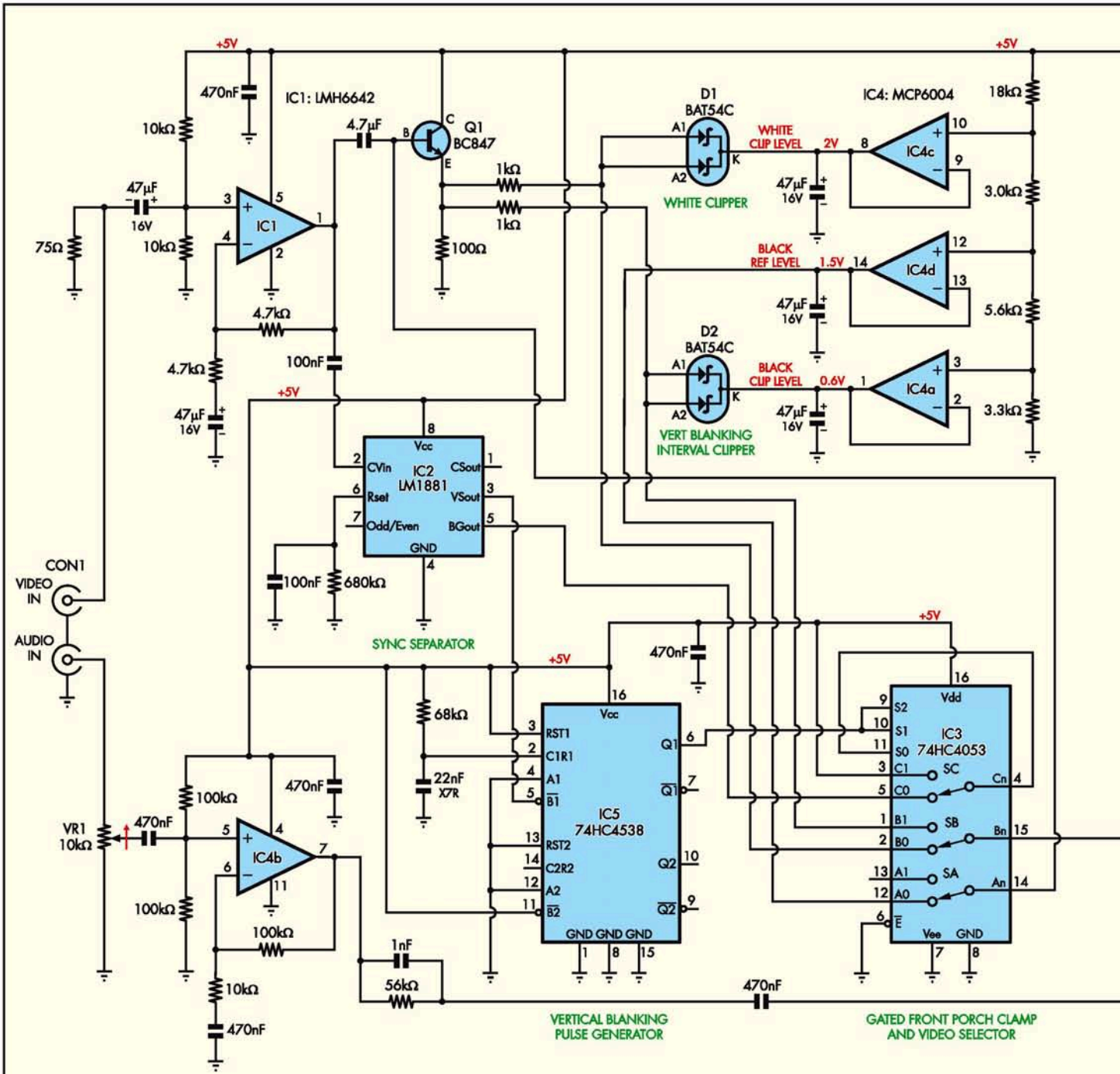


Fig.4: block diagram of the Modulator. IC2 detects the vertical sync pulse and starts timer IC5a, which controls an analog switch that changes the video output to a version containing only sync pulses during the vertical blanking interval. The rest of the time, D1 and IC2 combine to prevent signal levels above the maximum white level from passing through to the modulator, which also receives the processed audio. Variable inductors L1 and L2 allow the two carriers to be tuned.



VINTAGE ANALOG TV MODULATOR

B0 (pin 2) first. The cathodes of D1 are held at 2V by buffer op amp IC4c.

This reference level is generated from a string of four resistors across the regulated 5V rail. Given that schottky diode D1 will have a forward voltage of around 0.2V when conducting, this means that input pin B0 will be clamped at a maximum of around 2.2V.

This is 1.4V above the black level that we determined earlier would be present at the emitter of Q1 (ie, 2.2V - 0.8V).

Since we've applied a gain of two to the signal, that represents an increase of 700mV (1.4V ÷ 2) above the black level in the original signal; very close to the 715mV mentioned earlier for the correct white level. So D1 prevents the signal at pin 2 of IC3 from exceeding the desired white level.

During active line scanning, the signal at input pin 2 (B0) is fed through to output Bn (pin 15), which drives the base of PNP emitter-follower Q2.

Thus, Q2 buffers the video signal which is then fed through a 75Ω impedance-matching resistor and 470µF DC-blocking capacitor to the video output socket.

Note that the 75Ω resistor will form a voltage divider with the 75Ω cable impedance/input impedance of the TV.

Since IC1 already applied a gain of two to the video signal, the TV will receive a signal with the correct amplitude.

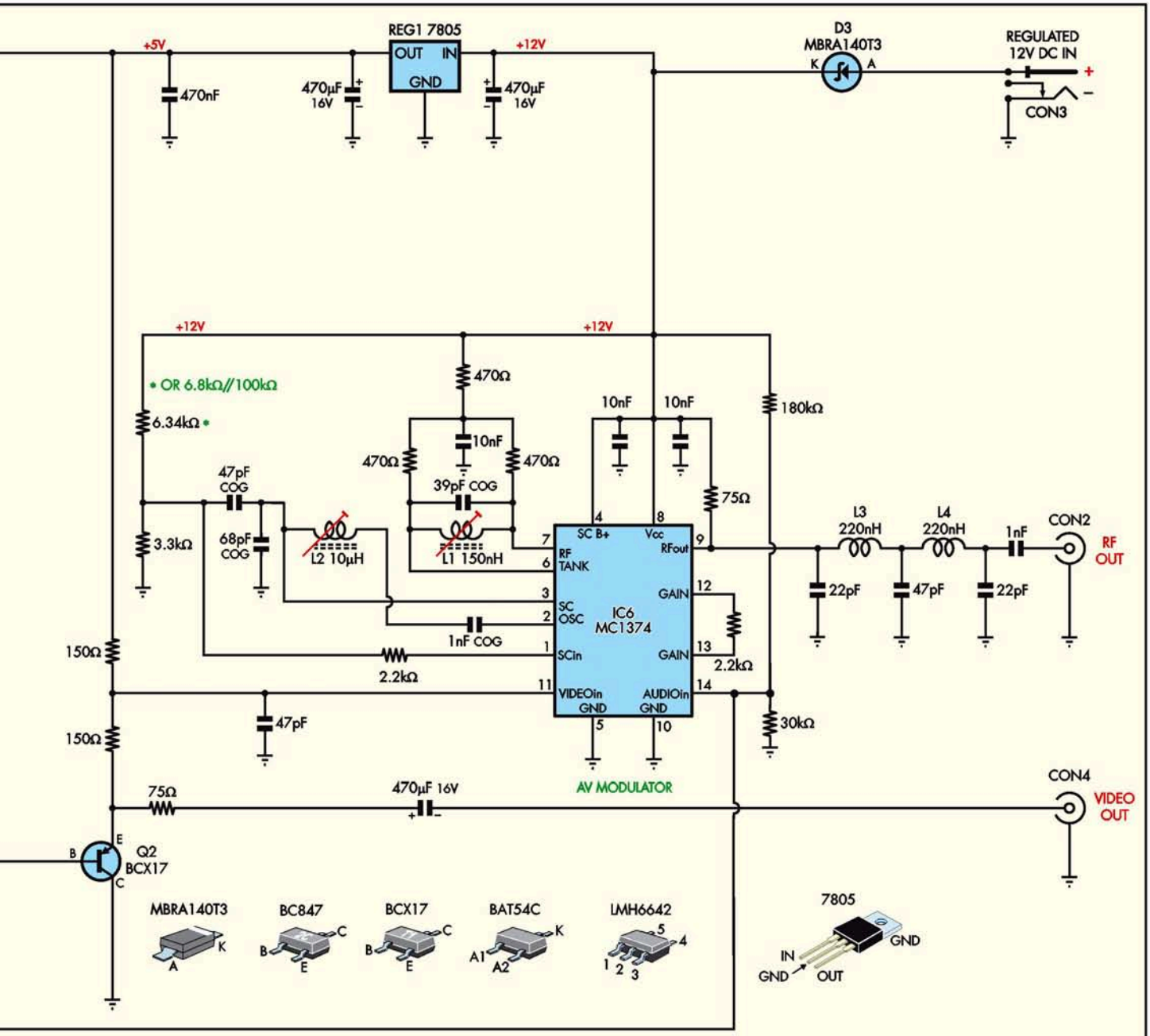


Fig.5: complete circuit of the Modulator. The video signal is buffered by IC1 (which also applies some gain), then buffered again by Q1 and clamped by diodes D1 & D2 before passing to analog multiplexer IC3. Its video output is then fed to another buffer transistor, Q2, and then onto the A/V modulator, IC6. It then generates a signal which is fed to the RF output, CON2, via a low-pass filter. The audio level is adjusted using VR1 and processed by IC4b before also being fed to modulator IC6.

Actually blanking the Vertical Blanking Interval

As mentioned earlier, the video signal from input buffer IC1 also passes through to IC2.

This is an LM1881 sync separator and this detects two control signals: the vertical synchronisation pulses (shown in Fig.1) and the colour burst/back porch (shown in Fig.2).

Its pin 3 output goes low for a fixed period when a vertical synchronisation pulse is detected while the pin 5 output goes low during the back porch/colour burst period.

The vertical sync pulse output from pin 3 is stretched by IC5a, a 4538 retriggerable monostable multivibrator. The length of the output pulse is set by the combination of a 22nF capacitor and 68kΩ resistor and this time constant was chosen to be equal to the remainder of the VBI.

The signal from the Q output of IC5a (pin 6) is fed to logic input S1 of multiplexer IC3 (pin 10). This switches the source of the video fed to buffer transistor Q2 to be from input pin B1 (pin 1) rather than Y0 (pin 2) so that during the VBI, the video signal sent to the TV set contains only the horizontal synchronisation pulses and is otherwise black.

The signal fed to input B1 is similar to the signal described earlier at B0, except that it is clamped by diode D2

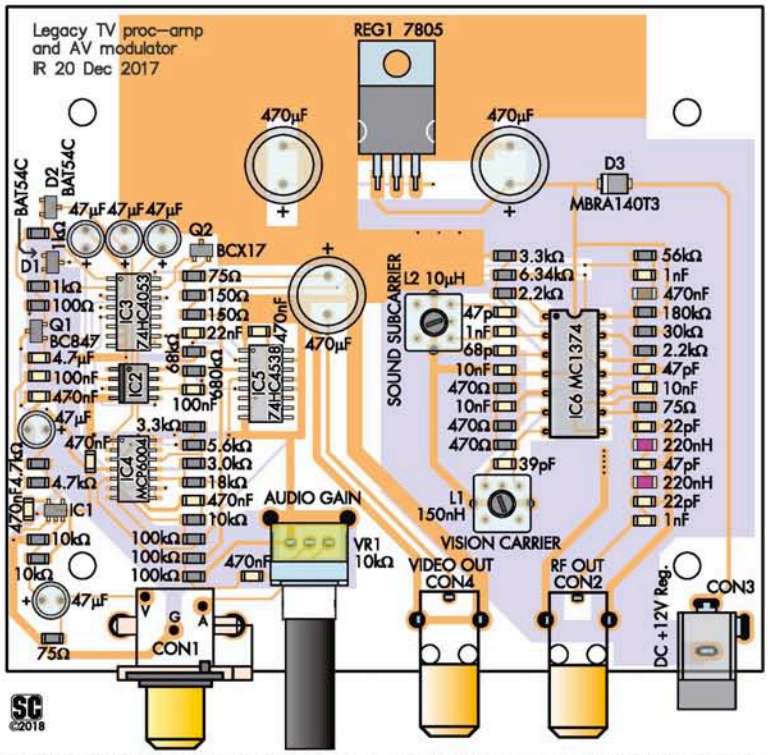


Fig.6: use this PCB overlay diagram as a guide during assembly. Most of the passive components, with the exception of the electrolytic capacitors, are surface-mounted, as are all the semiconductors, with the exception of IC6. Be careful to fit the ICs and electrolytic capacitors with the correct polarity.

rather than D1. D2's cathode is connected to a 0.6V reference level which is buffered by op amp IC4a (derived from the same divider string as the 2.0V reference mentioned earlier).

Since the black level of the video signal at the emitter of Q1 is around 0.8V, taking into account the ~0.2V forward voltage of D2, this diode will prevent any signal levels above the black level from passing through to input B1. Thus, the synchronisation pulses (which are negative) can get to input B1 but anything else during the VBI will be clipped off.

As a result, anything other than the sync pulse that may come from the video source during the VBI is not fed through to the TV.

By the way, because of the bias requirements of the vision modulator and the need to allow for diode drops, the reference voltages generated by the resistor chain are quite critical and inter-dependent.

A spreadsheet was used to calculate the best fit, using preferred-value resistors, to avoid the need for adjustments.

The back porch and black reference level

I explained earlier that the base of Q1 is held at +1.5V during the back porch to set the correct black reference level. This reference level comes from the output of op amp IC4d, which is in turn driven from the same four-resistor reference divider that produces the other two reference voltages.

The output of IC4d drives the base of Q1 when input A0 (pin 12) of analog multiplexer IC3 is connected to its respective An output (pin 14) when logic input S0 (pin 11) is low. This logic input is driven by the Cn output of the multiplexer, (pin 4). This part of the multiplexer is being used as a logic gate.

Since input C1 (pin 3) is tied high to +5V and input C0 (pin 5) is connected to the back porch/colour burst output of sync separator IC2, output Cn will only be low during the back porch period (ie, output pin 5 of IC2 is low) and when input S2 (pin 9) is low.

And input S2 is low most of the time but is driven high during the VBI, by the output of IC5a that was mentioned earlier.

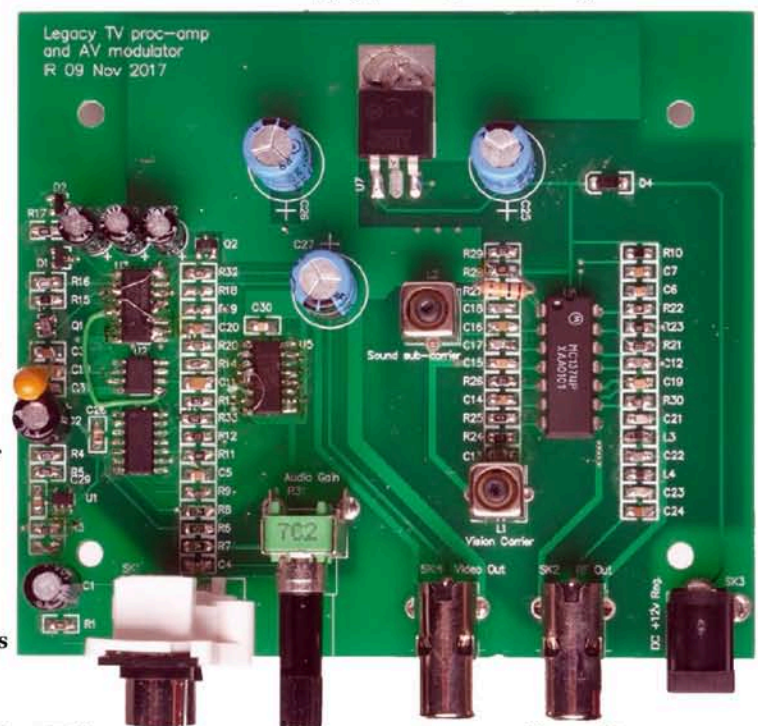
So basically, the base of Q1 is held at the +1.5V reference level during the back porch, except for during the VBI.

This means that the black level of the signal is "reset" at the beginning of each horizontal scan line but it is left unaltered during the VBI since other signals that are present during the VBI can be falsely detected as the back porch and thus could result in incorrect biasing.

The 4.7µF capacitor at the base of Q1 has a high enough value to preserve the correct DC levels during the VBI.

Audio processing

The audio signal from CON1 is fed to audio gain/volume control pot VR1 and then AC-coupled to non-inverting input pin 5 of the remaining op amp, IC4b. The signal is biased to a half-supply (~2.5V) level using two 100kΩ



This same-size photo matches the above component overlay in most respects, but is of an early prototype and so has a number of patches and added components (particularly around IC3). The final PCB design above has these changes incorporated.

resistors. A fixed gain of 11 times is applied, set by the ratio of the 100kΩ and 10kΩ resistors. Again, the bottom end of the divider is connected to a capacitor to ground, so that the DC bias of the inverting input and the output will also settle at 2.5V.

A simple filter network comprising a parallel 1nF capacitor and 56kΩ resistor provide audio pre-emphasis with a time constant of 50µs (treble boost), as required for the following FM modulator. The audio signal is AC-coupled to the modulator via a 470nF series capacitor so that the signal can be biased to 1.7V, to suit the modulator; this level is derived from the 12V rail using 180kΩ and 30kΩ resistors.

RF modulator

IC6, the MC1374, is designed specifically for this sort of job. Along with the audio signal just mentioned, which is fed into pin 14, The video signal at CON4 is also fed into IC6, at input pin 11. A 47pF capacitor to ground filters out any RF which may be present in the video signal, preventing it from affecting the operation of the modulator.

The MC1374 contains an RF oscillator, RF modulator and a phase shift type FM modulator, arranged to permit good PC board layout of a complete TV modulation system. The RF oscillator can operate up to approximately 105MHz, which makes it suitable for Band 1 VHF. The video modulator is a balanced type.

The choice of the MC1374 may seem unwise as this part is no longer in production. However, it is readily available from many sources on the web at a reasonable price. This is a much better situation than most that TV restorers have experienced!

Silicon Chip will have a stock of this IC available in the Online Shop, so you can order it at the same time as the PCB.

The modulated sound carrier and composite video information are fed in separately, to pins 1 and 11 respectively, to minimise crosstalk. The RF output is a current sink which can drive a 75Ω load.

Note that the PNP video buffer transistor, Q2, is not just used to provide a low impedance drive for the output socket. It also allows us to shift the video signal DC bias level to around 3.9V, as is required by IC6, to set the correct black level. (Note that due to the way IC6 works, the same DC bias level is used for pin 1).

This shift is due partly to the ~0.7V base-emitter junction forward voltage and partly because of the voltage divider comprising two 150Ω resistors between Q2's emitter and the 5V rail. These two resistors also reduce the AC amplitude of the video signal by half, compensating for the gain of two that was applied earlier by IC1.

IC6 contains two internal oscillator amplifiers which drive the RF tank between pins 6 and 7, to generate the video carrier, and the FM carrier tank

Parts list – Audio/Video Modulator for Analog (Vintage) TV sets

1 130x100x50mm light grey ABS instrument case [Altronics H0371]
1 double-sided PCB, 100 x 88mm, code 02104181
1 150nH variable inductor (L1) [CoilCraft 7M2-151] ***OR*** 1 SBK-71K coil former pack (Silicon Chip Online Shop Cat SC2746) plus 100mm length of 0.25mm diameter enamelled copper wire
1 10µH variable inductor (L2) [CoilCraft 7M2-103] ***OR*** 1 SBK-71K coil former pack [Silicon Chip Online Shop Cat SC2746) plus 900mm length of 0.25mm diameter enamelled copper wire
2 220nH SMD inductors, 2012/0805 package
1 2-way PCB-mount RCA socket, red/white (CON1) [Altronics P0210]
2 black PCB-mount low-profile RCA sockets (CON2,CON4) [Altronics P0207]
1 2.1mm or 2.5mm ID PCB-mount DC socket (CON3)
1 12V DC regulated plugpack with plug to suit CON3
5 No.4 x 6mm self-tapping screws

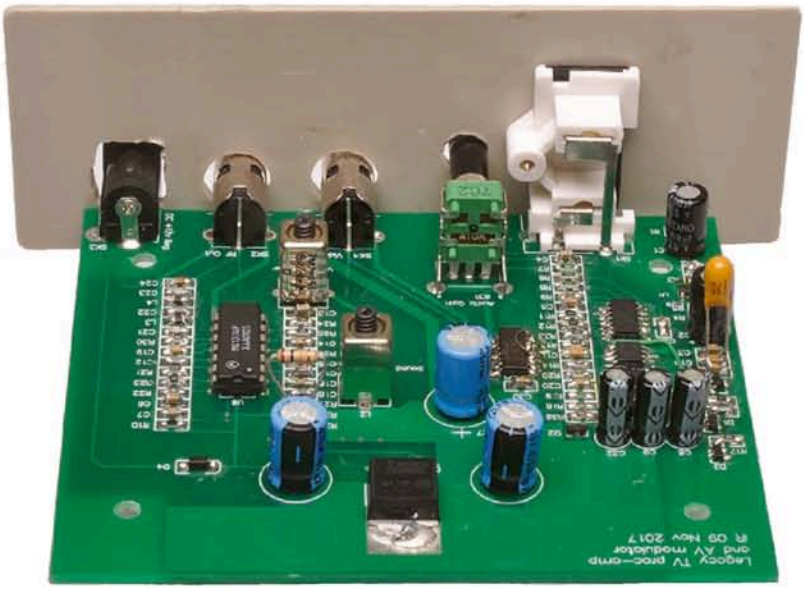
Semiconductors
1 LMH6642 high-bandwidth op amp, SOT-23-5 (IC1)
1 LM1881 sync separator, SOIC-8 (IC2)
1 74HC4053 triple two-channel analog multiplexer, SOIC-16 (IC3)
1 MCP6004 quad op amp, SOIC-14 (IC4)
1 74HC4538 dual monostable multivibrator, SOIC-16 (IC5)
1 MC1374P A/V modulator, DIP-14 (IC6) [Silicon Chip Online Shop Cat SC4543]
1 LM7805S 5V 1A regulator, TO-263 (REG1) ***OR***
1 7805 5V 1A regulator, TO-220, with leads cut short and bent to fit (see text)
1 BC847 NPN transistor, SOT-23 (Q1)
1 BCX17 PNP transistor, SOT-23 (Q2)
2 BAT54C dual schottky diodes, SOT-23 (D1,D2)
1 40V 1A SMD schottky diode, SMA package (D3) [MBRA140T3 or similar]

Capacitors (all SMD 2012/0805, 16V X7R unless otherwise stated)
3 470µF 16V radial electrolytic
5 47µF 16V radial electrolytic
1 4.7µF
6 470nF
2 100nF
1 22nF
3 10nF
3 1nF
1 68pF
3 47pF
1 39pF
1 22pF

Resistors (all SMD 2012/0805, 1%)

1 680kΩ	1 180kΩ	3 100kΩ	1 68kΩ	1 56kΩ
1 30kΩ	1 18kΩ	3 10kΩ	1 6.34kΩ	1 5.6kΩ
2 4.7kΩ	2 3.3kΩ	1 3.0kΩ	2 2.2kΩ	2 1kΩ
3 470Ω	2 150Ω	1 100Ω	3 75Ω	

1 10kΩ 9mm horizontal log pot with long 18-tooth spline shaft (VR1) [Altronics R1918]



The PCB attaches to the rear panel via a single screw on the input socket; the assembly is held in the case via four self-tapping screws while the rear panel slots into the vertical guides in the case. This holds the whole thing rigid.

between pins 2 and 3, to generate the audio carrier.

Both of these tanks are based on variable inductors, to allow them to be tuned to the required frequencies, as well as capacitors, to make them resonant.

Since the video carrier, at 50-100MHz, is at a much higher frequency than the audio carrier (5.5MHz), the inductance value of L1 (0.15µH) is much lower than L2 (10µH).

This unit is not crystal locked but tuned to operate on channel 2 (64.25MHz), since this channel is now unused and able to be tuned by any TV. It is a simple matter to re-tune it to any band 1 channel (1, 2 or 3).

Note that it may be possible to tune to channels 0 or 4 but neither of these can be received by early TVs with 10-channel VHF tuners, so they would not be good choices. Later Australian sets had 13-channel tuners.

The design could have used a crystal for maximum stability but a suitable custom crystal would be expensive and the LC oscillator stability is excellent anyway. A PLL could also have been used but would have greatly increased complexity.

The configuration of the video RF tank (a parallel resonant circuit) is pretty much identical to the sample circuit in the MC1374 datasheet, with the exception being the 10nF capacitor; its suggested value was 1nF in the data sheet. Its purpose is to filter the applied supply voltage, so a larger value should be better.

Similarly, the FM carrier oscillator components (series resonant) are very similar to those specified in the MC1374 data sheet with the only real difference being the values of the 47pF and 68pF load capacitors, which have been tweaked to work better with the properties of inductor L2.

The balanced modulator gain resistor is the recommended value, at 2.2kΩ. This controls the modulation depth at the output.

The output is terminated with a 75Ω resistor from the 12V rail, which also supplies current to the modulator circuitry.

The output signal then passes through a double-pi low-pass LC filter (fifth order) to clean up the sidebands. It would have been better to use a proper "vestigial sideband filter" but these require tuning.

The downside of this simple approach is that it's possible to tune the TV to the opposite sideband. However, this will result in poor picture and sound quality which is easy to identify. In this respect, it's no different to typical VCR modulators.

The power supply is simple. We rely on the plugpack to supply a regulated 12V rail which is used to power the A/V modulator (IC6) more-or-less directly, via reverse polarity protection schottky diode D3.

A 470µF filter capacitor is provided, which also acts as the input bypass capacitor for 5V regulator REG1, which supplies the rest of the circuitry. It too has a 470µF output filter capacitor.

Construction

As all components mount on a single PCB, construction is relatively straightforward. The PCB then fits neatly into the plastic instrument case.

The PCB overlay diagram Fig.6 and photograph show where all the components go.

Most of the parts are SMDs (surface-mount devices) but there are some through-hole parts too, notably the connectors, electrolytic capacitors and IC6.

Because most of the SMDs have widely-spaced pins, you shouldn't have any difficulty soldering them in. IC1 is the one exception, with closely-spaced leads, but since it only has five pins (two on one side and three on the other), it shouldn't prove too difficult.

Soldering IC1 is a good place to start. Since it has a different number of pins on each side, its orientation is easy to figure. Tack-solder one of the corner pins (on the side with two pins) and then check that the other pins are correctly aligned over their pads using a magnifier.

If not, re-heat the solder and nudge it into place. Repeat until it's properly aligned, then solder the other four pins. This is easier if you apply a little flux paste to the pins first.

Don't worry about bridging the three that are close together; if this happens, simply apply a little flux paste and then apply some thin solder wick and heat and the bridges should disappear.

Add some flux paste and re-heat the initial pin that you tack soldered to ensure the joint is not cold.

Clean off any residue using alcohol or flux cleaner and check carefully under magnification (and with good light) that all five solder joints have good fillets. You can then move on to the other SMD ICs, IC2-IC5.

You can use a similar approach but you should find these considerably easier due to the larger pin spacings. Watch the polarity though; all the other ICs can be soldered in one of two orientations and only one is correct. Refer to the photo and the overlay diagram, Fig.6, to see the correct orientations. In each case, pin 1 should go towards the top edge of the board.

Pin 1 of the IC is normally indicated with a dot or divot in that corner, as well as the pin 1 side having a bev-

elled edge. Make sure the orientation matches that shown in Fig.6 before soldering all the pins.

Next, fit diodes D1 & D2 and transistors Q1 & Q2. These are all in 3-pin SOT-23 packages, similar to IC1 but since they have fewer pins, the spacings are larger, making them quite easy to solder.

Just don't get them mixed up since they look virtually identical. Use the same technique as before, tack soldering one pin and then soldering the rest before reflowing the first joint.

It's best to solder the passive SMDs next, ie, the resistors, ceramic capacitors and the two 0.22µH chip inductors, L3 & L4. The technique is essentially the same but this time you only need to make two solder joints per component.

In each case, make sure it is sitting straight and flat on the PCB before soldering the second pin.

Also, it's best to wait for a few seconds after making the first joint before attempting the second, since if it's still liquid, you will end up nudging the part out of place.

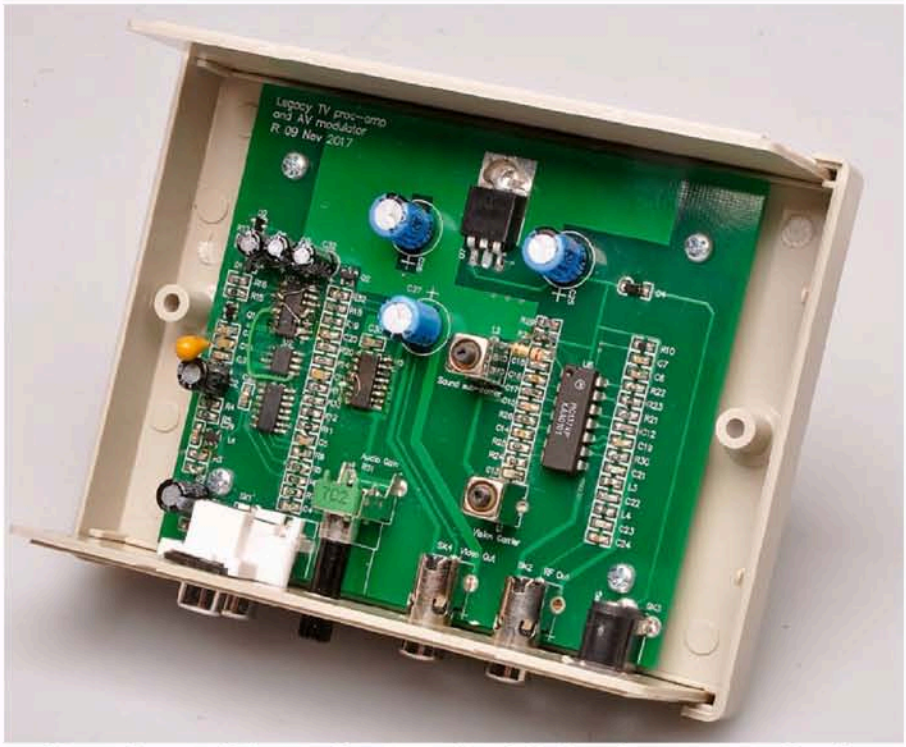
If the component moves when you go to make the second solder joint, even though you've waited a few seconds, that suggests the first joint hasn't adhered to the PCB pad properly.

The SMD resistors will have a code printed on them to indicate their resistance. For example, a 47kΩ resistor will be marked with either "473" (ie, 47×10^3) or "4702" (ie, 470×10^2).

However, SMD capacitors will probably not have any markings and the smaller inductors may not either. If your DMM has provision for it, measure them to confirm their value before placement.

The final SMD component is the regulator, REG1. We have specified an SMD version of the 7805 since that is what was used to build the prototype, however, it is possible to mount a standard 7805 regulator if you bend the leads so that they will sit against the PCB and then cut them short so that they don't protrude past the ends of the mounting pads.

Regardless of whether you use an SMD regulator or adapt a through-hole type, the tab has a lot of thermal inertia so we suggest that you spread a thin layer of flux paste on the large tab as well as the three smaller pads, turn up your soldering iron's temperature and then solder one of the smaller pins.



And here's how it all fits together, immediately before the case top is placed in position (it only fits one way) and the two case screws are inserted from underneath and tightened.

You can then check if the tab is properly located and start applying solder to the junction of the tab and the PCB.

You will probably have to hold the iron there for some time (10 seconds or more) to get the regulator and PCB hot enough for the solder to flow.

Once that happens, feed the solder in and then quickly remove the iron and you should get a nice fillet between the tab and PCB. You can then solder the remaining pins.

Alternatively, if you have a hot air rework station, you can apply solder paste and then carefully heat the regulator and surrounding PCB area with hot air until the solder melts.

Through-hole parts

There are just a few through-hole parts and most of them are easy to solder. Start with IC6, being careful to ensure it's correctly orientated before soldering it in place. We don't suggest that you use a socket; it's better to solder the IC directly to the PCB.

Follow with the electrolytic capacitors. They are different sizes so it should be obvious where each one goes but do pay careful attention to orientation. The longer lead goes into the hole marked + on the PCB and in Fig.6, while the opposite side (ie, negative end) of the can should be marked with a stripe.

Fit RCA connectors CON2 and CON4 next, followed by DC socket CON3. In each case, ensure the connector is pushed fully down onto the board before soldering the pins.

Inductors L1 and L2

While you can purchase these inductors from the CoilCraft website, if you're only buying two then the postage charge will be prohibitive.

Luckily though, the CoilCraft parts have an identical footprint to the SBK-71K coil formers that we already stock in the Silicon Chip Online Shop for other projects. These are supplied with a ferrite slug which can be adjusted for tuning the oscillators, just like the CoilCraft parts.

Wind inductors L1 and L2 using the following procedure:

1) cut a ~900mm length of 0.25mm diameter enamelled copper wire and strip the insulation off one end (by about 5mm) using a sharp hobby knife or emery paper.
2) tin the end of the wire and wrap it around one of the pins at either end of the side which has three pins (ie, not the middle pin).
3) push the wire as close to the base of the former as possible and solder it to the pin. Be quick since if you

apply too much heat, the pin could come out of the former.

Try to avoid getting too much solder on the rest of the pin since that could prevent it from being inserted into the PCB later.

4) pass the wire up the side of the former, through the notch in the base and wrap it around the cylindrical shaft.

5) wind 45 turns as neatly as possible. With wire this fine, it's almost impossible to do it layer-by-layer but it's best to avoid making it a total jumble.

Keep the turns below the collar that's about 2/3 of the way up the cylinder, so that they can't slip over the top.

6) bring the last turn down to the opposite pin on the side with three pins and cut the remainder off. Strip the insulation from the end of the wire, tin it, wrap it around that pin and solder it in place as you did the other end. See the below photo for an idea of what the finished coil should look like.

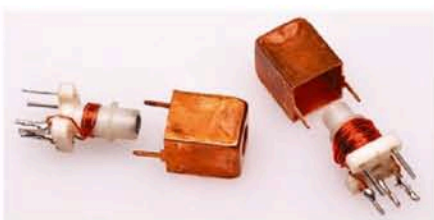
7) measure the resistance between the two pins. You should get a reading of 0.25-0.3Ω (remember that your multimeter leads will have some resistance so if possible, short them and null/zero it before making the measurements).

If you have an inductance meter, you can measure the coil now. It should be around 8μH.

8) screw the ferrite slug into the top of the former until it's fully inside and then place the shield can over the top, with its mounting flanges on the sides not occupied by pins.

9) L2 is now complete. Use the same procedure to wind L1, except that only five turns of wire are required. The resistance should be much lower – under 0.1Ω.

Having finished winding the two coils, solder them in place where shown in Fig.6. Make sure you don't get them mixed up. L2 is the one with more turns and a higher winding resistance.



You *can* buy L1 and L2 pre-made but winding them yourself, using SBK-71K coil formers from the SILICON CHIP Online Shop, will prove much cheaper. L1, 150nH, (5 turns) is on the left, while L2, 10μH, (45 turns) is on the right.

Final assembly

All that's left now is potentiometer VR1 and dual RCA socket CON1. Fit these both where shown in Fig.6; try to keep the pot shaft parallel to the PCB while you solder its mounting pins.

You can then slip the rear panel over the connectors and pot shaft and lower the whole assembly into the bottom of the case.

Affix it to the base using four self-tapping screws.

Tuning and testing

There are only three adjustments to make: tuning the vision carrier and sound sub-carrier by adjusting the values of L1 and L2 respectively and adjusting pot VR1 to give the correct sound level.

Our prototype drew 42mA at 12V, so a good way of checking that you have assembled your unit correctly is to connect a DMM set to measure milliamps in series with the 12V power supply when you first power it up.

If you get a reading between about 30mA and 50mA then that suggests there are no serious faults and it's probably working correctly.

Having verified that the circuit is drawing an appropriate amount of current, the next step is to adjust the two oscillators by turning the tuning slugs in L1 and L2 with a plastic adjustment tool.

We've come up with three procedures for this, depending on what equipment you have.

The easiest one is if you have a spectrum analyser. Connect it to the RF output, power the unit up and adjust L1 so that the largest peak is centred on 64.25MHz. Adjust L2 so that the smaller peak is centred on 69.75MHz. You will likely see an image of the carrier 11MHz below this (ie, 5.5MHz below the main peak); ignore that one.

If you have a 100MHz+ oscilloscope, connect a tight loop of wire to the end of one of the probes and place it near the 39pF capacitor just above L1. Don't make a direct connection to the circuit or you may pull the oscillator off-frequency.

Adjust L1 to read 64.25MHz on the scope display. Then move the probe coil near the 68pF capacitor between L2 and IC6 and adjust L2 for a reading of 5.5MHz.

If you don't have equipment that can read these frequencies, the simplest approach is to hook the RF output of the unit up to the antenna input on an analog TV that you know works, tune the TV to channel 2 and feed some video into the input.

If TV has automatic fine-tuning (AFT), turn it off.

Adjust L1 so that image just breaks up at the edge of the sound carrier. Back it off until you have a clear image.

If you encounter significant ringing in the image while you are tuning, you are attempting to tune to the wrong sideband. Wind the core right out and start from the top position.

Once you have a clear picture, you'll need to tune the sound. It helps to display an image with a lot of white text, such as a DVD copyright message.

Tune L2 for minimum noise in the sound – the correct adjustment is a definite null, either side of which the noise increases.

Connect an audio signal to the unit's input and turn up VR1 (to about halfway) to verify that the sound is properly fed through.

If you adjusted L1 and L2 without using a TV, now is a good time to hook the unit up to a TV and tune in to channel 2.

With nothing connected to the video or audio inputs, you should get a black screen and silence. Then all you need to do is plug in a video and audio source and verify that you get a clean picture and sound.

As for setting VR1, which controls the audio modulation depth, basically, you just need to turn it up as high as possible before you notice any distortion in the sound, then back it off a little bit.

If you can't get the unit to work, feed the Video Out signal to the A/V input on a modern TV while feeding a video signal into the input and check that you get a good picture. That will verify that the video processing circuitry is working OK. If not, check the circuitry around ICs1-5.

If you can verify that the video output is working correctly but you still can't tune into a signal on your vintage TV, that suggests a problem with IC6 or one of its associated components, including L1 and L2.

Re-check that you have tuned the two oscillators correctly. SC

Vintage Radio

By Associate Professor Graham Parslow

Philips 1953 portable 5-valve model 148C radio

Photo courtesy of Kevin Poulter, President of HRSA

The Philips 148C was one of a series of portable radios produced by Philips under different brand names, including Mullard and Fleetwood. All had the same construction and broadly similar circuitry. Their common case was an interesting design, with all controls and the dial concealed by a shutter. Finally, the case panels were made from aluminium, a fairly exotic material in the later 1940s and 1950s.

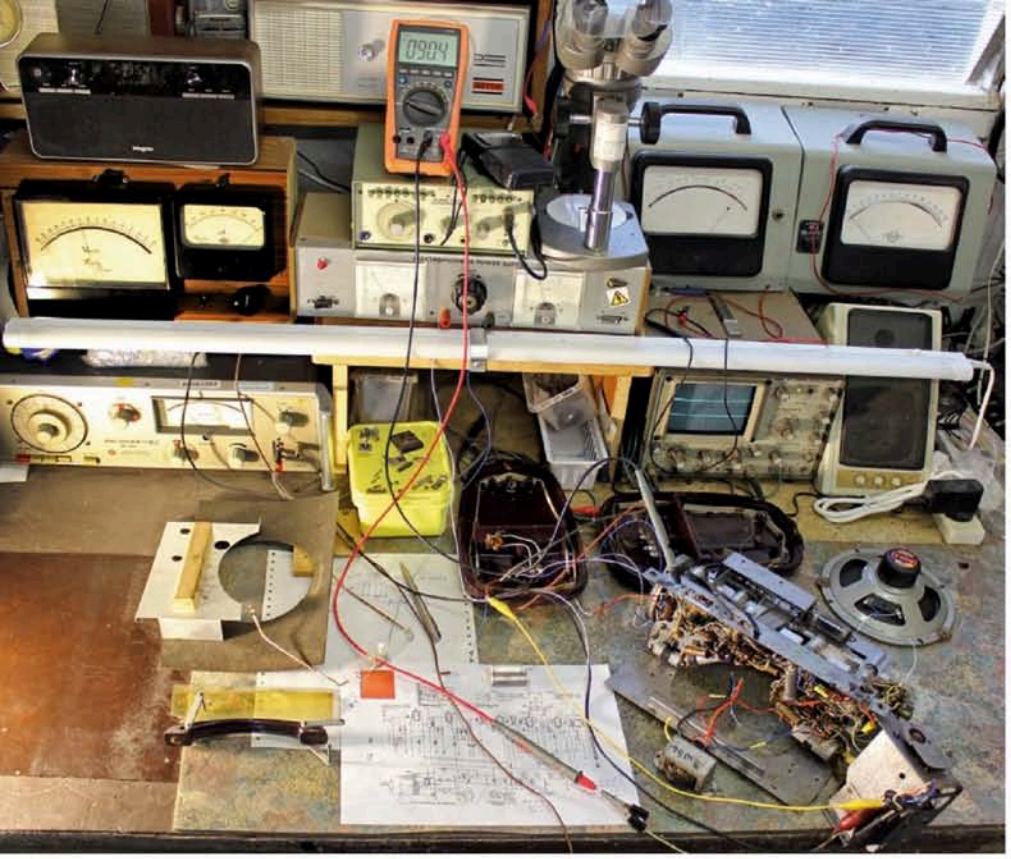
We now take the aluminium can for granted since billions of them are made every year. However the first aluminium products were extremely expensive. The original Auld Mug of 1857 (The America's Cup) was made of aluminium and predated industrial production that commenced in 1888.

Two world wars necessitated quantity production of aluminium for aircraft. Aluminium gathered mystique from its use in aircraft while becoming ever more available for other uses in the 1940s. It is surprising that Philips were one of the few radio manufacturers to use it for making a case, although RCA in America manufactured a nearly identical case.

Regardless of the lightness of aluminium, the weight of the Philips 148C is a substantial 6.3kg, even without batteries. In fact, it is only the outer panels which are made from aluminium while the end panels are of Bakelite. The chassis is steel and the internal construction is fairly conventional for the time.

The Philips 148C is a full-featured superhet with an RF stage. With the exception of the full-wave rectifier (which is a 6V4 in my set but could be an EZ82), all of the miniature valves are battery types such as 1T4 and 1R5.

Its RF stage makes it a sensitive performer and it readily pulls in weak stations. While it might be thought that the aluminium panels would offer a degree of shielding and would thus reduce signal pickup by the aerial coils, they have little practical effect in this regard.



Since the Philips 148C has its two aerial coils integrated into the case, temporary wiring was needed to connect the coils up for testing.

Opening the shutter on the front of the case reveals the two controls (one for volume and one for tuning), at opposite ends of the slide-rule dial.

The shutter actually operates the On-Off switch while the changeover from battery to mains operation is achieved by inserting the mains plug into the socket on the rear of the case.

These switches are worked by springs and levers that add complexity to the mechanical construction of the radio. A friend who ran a radio repair shop told me that he spent a day changing the volume control on one of these radios because of the way the shutter-operated switch made access to the volume pot so difficult.

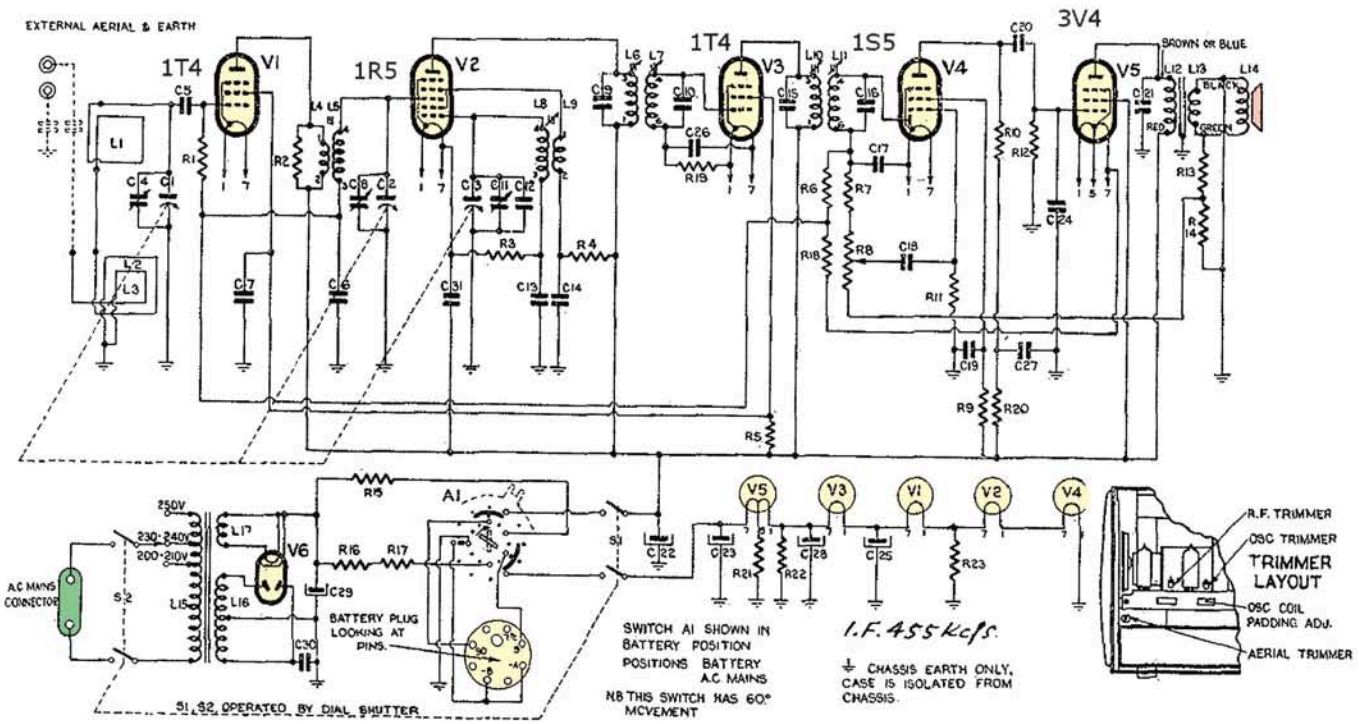
The front end has two separate loop coils for the aerial and these are built into both ends, using the Bakelite mouldings as retainers. Although the ends look the same externally, the left and right differ internally to accommodate the coils and their terminations.

As can be appreciated from the accompanying photographs, having two aerial coils added to the challenge to set up this radio on the workbench, after the casing was disassembled for restoration.

The short fly leads from the radio to the aerial coils must be unsoldered to remove the chassis. This means that temporary wiring is needed to connect the aerial coils for working at the bench.

Circuit details

The aerial coils are wired in series and act with the first gang of the three gang tuning capacitor (C1) to provide RF input to the 1T4 RF preamplifier valve. A second tuned circuit involving (C2 and L5) feeds signal to the grid of the 1R5 mixer-oscillator valve. The 1R5 additionally receives tuned input from the local oscillator formed by C3 and L8.



Apart from the full-wave rectifier which enabled operation from the 240VAC mains, all the valves are miniature battery types and it is a conventional superhet with a tuned RF amplification stage.

The intermediate frequency is 455kHz and is selectively passed on by the first IF transformer to the IF amplifier valve, another 1T4. The two IF transformers are of the relatively miniature type that Philips developed in the early fifties. The preceding model, type 148 of 1950, featured full-size cylindrical IF coils.

The tuning capacitor is also relatively small, with brass plates (not aluminium). Even so, this is still a cluttered layout with difficult access to many components, as can be seen from the picture of the front of the chassis with the speaker removed.

The 1S5 detector and audio preamplifier has only one diode that serves the double function of detection and providing AGC to the first two valves via resistors R6 & R1 and inductor L5.

The volume control potentiometer changes the signal level fed to the grid of the 1S5. The preamplified audio signal then passes to a 3V4 pentode output stage proving a modest level of 250mW or so. In practice this is quite satisfactory when coupled to the 6-inch Rola type H speaker.

Oddly, Philips reduced the speaker to a 5-inch unit in later variations of this radio (model 168). To my ear, the later ones do not sound as good as this one.

The one series valves (1T4, 1R5 and 1S5) are the standard set for portables of the late 1940s and the 1950s, used by almost every manufacturer. In combination with the 3V4 output pentode these valves were a proven combination for performance and efficient battery usage. They are not rare but the 1R5 and particularly the 3V4 are prone to fail and are becoming harder to obtain.

The radio ran at 90V HT with a drain of 10mA and 9V LT with a drain of 50mA. For portable operation, the battery was a combination type incorporating 90V and 9V sections, such as the Eveready 753, and was connected via a single plug.

For mains operation, the 6V4 full wave rectifier produces the HT and the LT, using ballast resistors to reduce the voltage to 9V for the series-connected valve filaments. The "one" prefix on the valves indicates a nominal filament voltage of 1V, but these valves barely operate at one volt.

Greater than 1.2V is needed to ensure efficient emission from the filaments. The 3V4 (V5) nominally requires 3V for the filament, however this is two 1.5V filaments in series and in parallel the filaments can work from 1.5V.

The unrestored aluminium case with the dial shutter closed and badge removed. The radio does not have an on/off switch, but instead is turned on by opening the shutter.

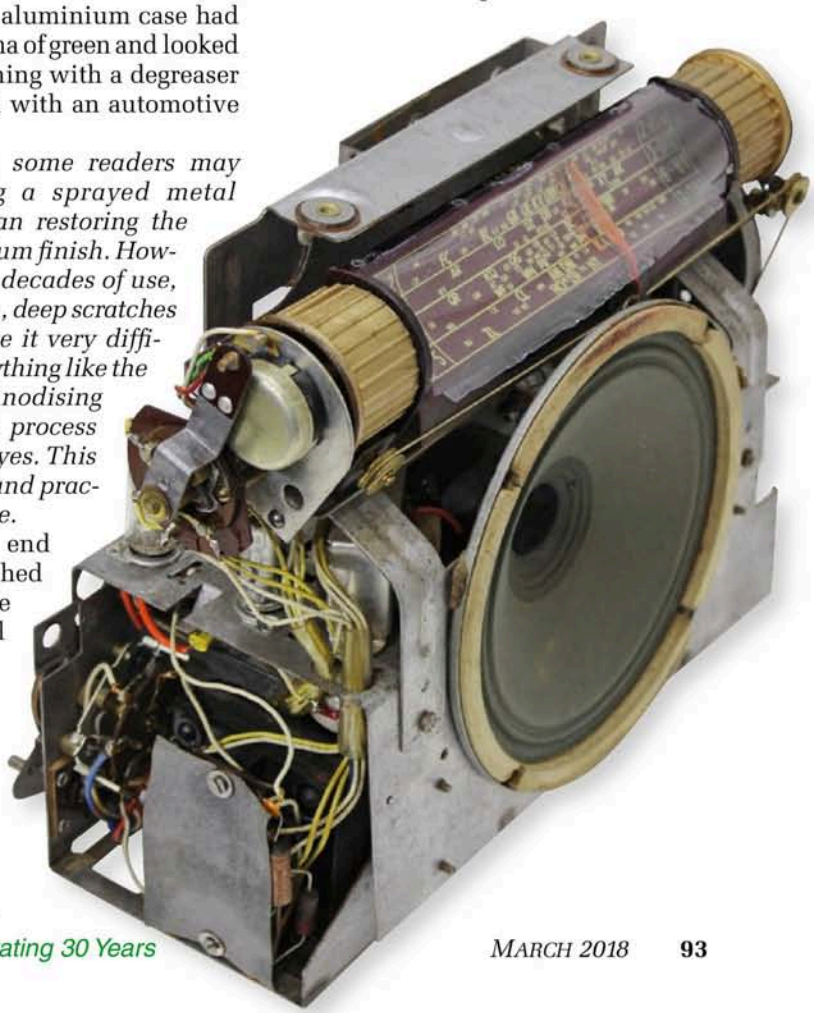
Restoration work

The anodised aluminium case had developed a patina of green and looked tired. After cleaning with a degreaser it was resprayed with an automotive chrome finish.

Editor's note: some readers may object to using a sprayed metal finish rather than restoring the original aluminium finish. However, after many decades of use, surface corrosion, deep scratches and pitting make it very difficult to obtain anything like the original finish. Anodising is not a simple process and it involves dyes. This is a satisfactory and practical compromise.

The Bakelite end pieces were polished with car wax. The yellowed dial cover with a hole (see picture of the front of the chassis before restoration) was replaced with acetate sheet, heat-moulded to shape.

This was challenging because the width needs to be precise to fit into the



This end view shows part of the mains on/off switch which was operated by the shutter at the front of the case.

This view shows the front of the chassis with speaker removed. Interestingly, the tuning gang has brass plates, whereas most production tuning gangs at the time used aluminium plates.

small channels at either end of the dial and the bottom lip must be reinforced to remain straight across the span.

A new Philips logo for the centre of the speaker grille was created by using laser-printed acetate sheet glued to metal-coated card.

Troubleshooting the circuit

The electrical restoration of this radio proved more challenging. Initially there was no sound at all from the speaker, using bench supplies to provide 9V LT and 90V HT via the battery plug (see the picture of the bench arrangement).

The 9V supply current was 50mA, indicating continuity of the heater filaments. In valve portables there is no visible glow of the filaments to indicate open-circuit heaters so current measurement is an important diagnostic tool.

But the 90V line was drawing only 3mA (whereas it should have been 10mA or more, if everything was working). For reasons that I suspect relate to operating at a relatively low voltage, portable valves have a high frequency of failure of pin connections and I routinely clean the pins before powering up.

A signal tracer at the volume control showed that detected (rectified) audio was being delivered from the 1S5. Since there was absolutely no sound from the speaker, it was detached and its voice coil checked for continuity. It was OK.

Detaching the speaker also gave access to many components otherwise inaccessible (see the picture of the front of the chassis).

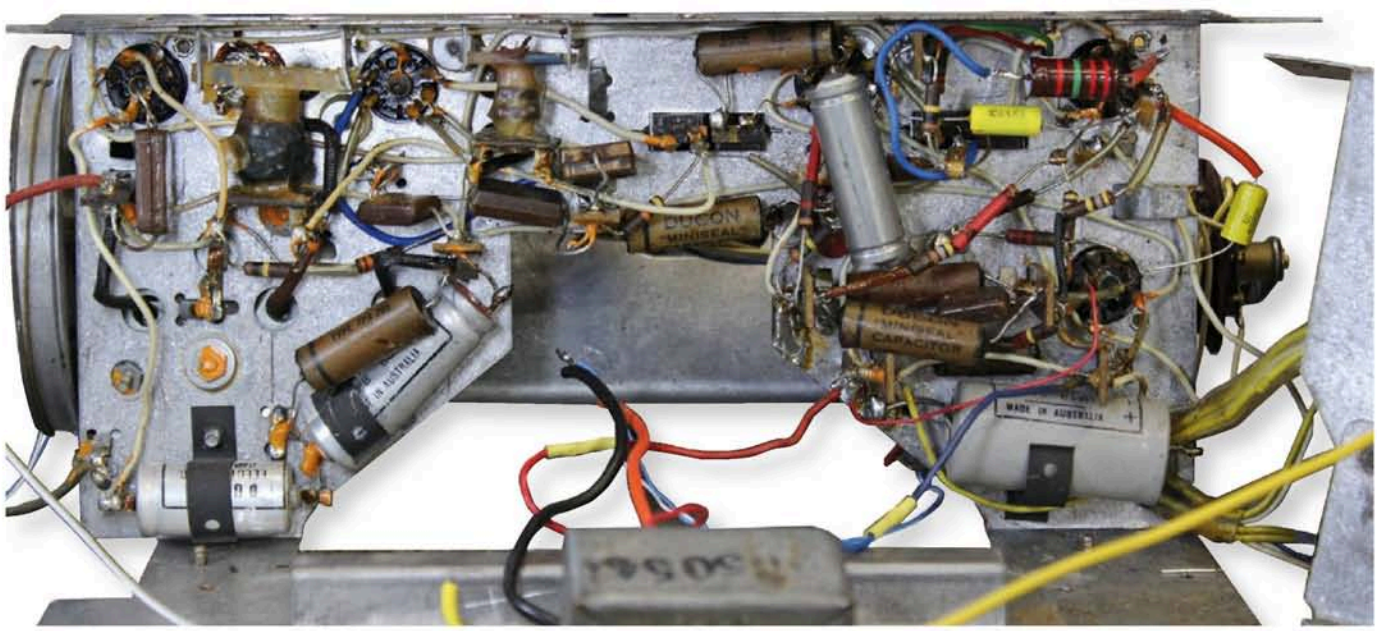
The next fault possibility suggested by the low HT current was an open-circuit primary in the output transformer.

This annoyingly common fault proved to be the case. When the output transformer is open-circuit there is no HT to the anode of the 3V4 output valve so it cannot conduct current.

Then came an "Oh bother" moment because the speaker transformer nuts and bolts were buried behind other components and the upper superstructure made the transformer captive, even if the bolts were removed.

The practical solution was to add a replacement transformer to a bracket below the speaker mounting and leave the original in place.

This will prevent a standard size battery being housed in that space. However, this set has a mains power



Even though the case was manufactured from aluminium panels, the chassis was made from plated steel and in other respects the construction was entirely conventional. Surprisingly, not many of the paper capacitors needed to be replaced.

supply, so it was a reasonable sacrifice.

But sadly the radio was still not working after replacing the output transformer. This led to measuring voltages around the 3V4 and checking whether audio was delivered to the grid.

The result was flabbergasting. A blue wire from IF transformer 2 might have provided screen voltage but it was soldered to pin 6 which is not connected. The audio feed from the 1S5 was connected to pin 3 (the screen) rather than pin 6 (the grid) that had nothing at all connected.

My first thought was that the cowboy who did this had incorrectly counted the pins anticlockwise rather than clockwise to create this mess, but that did not explain the mistakes. It was a case of that person having the wrong data for the valve and/or incomprehensible stupidity.

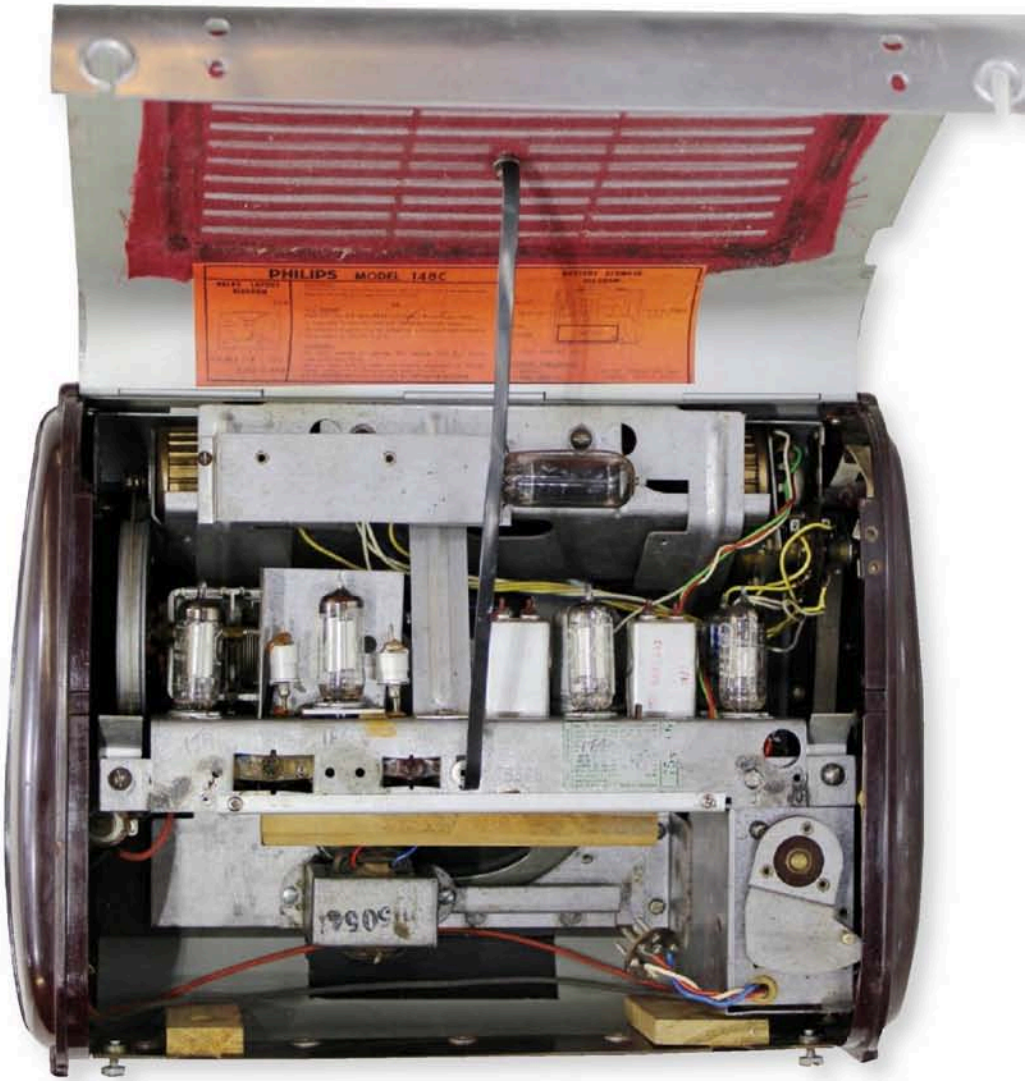
The picture of the components under the chassis shows the radio after the correct pin connections were sorted out for the 3V4. But even then, the radio still did not work. The feed capacitor from the 1S5 to the 3V4 (C20) was replaced but there was no audio signal passing through.

Finally, checking voltages at the 1S5 revealed the last problem. There was no screen voltage because R9 (3MΩ) had gone open-circuit. Replacing R9 was the last step to restoring normal function.

Luckily, the 1S5 still acted as a detector even when it could not function as an audio preamplifier.

After fixing the problems, the radio was run from the 230VAC mains using a proprietary plug inserted into the rear of the case. The power transformer and mains socket are awkwardly tacked on below the main chassis at the left-hand side and multiple wires lead up to the 6V4 rectifier and switching circuit mounted at the top.

Everything about the mechanical and electrical construction of this radio is challenging. However, all is well that ends well. It was gratifying to restore this radio to a good final appearance and excellent performance. SC



Not all of these portables made by Philips were equipped for mains operation as can be seen by the add-on section above involving the 6V4 full-wave rectifier just below the orange label.

Philips sold this radio under three brand names: Philips Model 148C (as shown to the right), Fleetwood Model 1052D and Mullard Australia MABS 1052. The valve line-up was the same for each brand.

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BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSiC-D Amp board and CLASSiC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
Li'l Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	SC2892	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	1510815	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60Hz TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
EFUSE	APR 2017	04102171	$7.50
SPRING REVERB	APR 2017	01104171	$12.50
6GHz+ 1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICROBRIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50
10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017	SC4281	$15.00
RAPIDBRAKE	JUL 2017	05105171	$10.00
DELUXE EFUSE	AUG 2017	18106171	$15.00
DELUXE EFUSE UB1 LID	AUG 2017	SC4316	$5.00
MAINS SUPPLY FOR BATTERY VALVES (INC. PANELS)	AUG 2017	18108171-4	$25.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER	SEPT 2017	01108171	$20.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER PANELS	SEPT 2017	01108172/3	$20.00/pair
3-WAY ADJUSTABLE ACTIVE CROSSOVER CASE PIECES	SEPT 2017	SC4403	$10.00
6GHz+ TOUCHSCREEN FREQUENCY COUNTER	OCT 2017	04110171	$10.00
KELVIN THE CRICKET	OCT 2017	08109171	$10.00
6GHz+ FREQUENCY COUNTER CASE PIECES (SET)	DEC 2017	SC4444	$15.00
SUPER-7 SUPERHET AM RADIO PCB	DEC 2017	06111171	$25.00
SUPER-7 SUPERHET AM RADIO CASE PIECES	DEC 2017	SC4464	$25.00
THEREMIN	JAN 2018	23112171	$12.50
PROPORTIONAL FAN SPEED CONTROLLER	JAN 2018	05111171	$2.50
WATER TANK LEVEL METER (INCLUDING HEADERS)	FEB 2018	21110171	$7.50
10-LED BARAGRAPH	FEB 2018	04101181	$7.50
10-LED BARAGRAPH SIGNAL PROCESSING	FEB 2018	04101182	$5.00
NEW THIS MONTH			
TRIAC-BASED MAINS MOTOR SPEED CONTROLLER	MAR 2018	10102181	$10.00
VINTAGE TV A / V MODULATOR	MAR 2018	02104181	$7.50
AM RADIO TRANSMITTER	MAR 2018	06101181	$7.50

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Receiving vertically polarised VHF TV

I am very interested in the 6-element VHF TV antenna featured in the February issue. It looks as though it could solve some TV reception problems that we are experiencing.

However, the VHF TV transmitters in the Manning Valley in NSW are vertically polarised, not horizontally polarised, as is the case in Australian metropolitan areas. So can I just mount the antenna so that all the elements are vertical or is it more complicated than that? (T. D., Taree, NSW)

● Unfortunately, it is more complicated. As presented in the February issue, the mast is shown as attached to the boom between the folded dipole and first director element.

That's fine when the antenna is set for horizontally polarised TV broadcasts but if the attachment is placed in the same position on the boom when the antenna elements are vertical, the metal mast will interfere with the operation of the folded dipole and all the other elements, to a greater or lesser extent.

The normal way to avoid this problem is to use a non-metallic mast which could be made of fibreglass or timber. Where do you get a fibreglass mast? One suitable source would be to adapt the telescopic handle from a long-handled pruner.

Of course, the conventional approach is to attach the mast to an extension of the boom, behind the reflector element. This was done with the vertically polarised DAB+ antenna which we presented in the November 2015 issue (siliconchip.com.au/Article/9394).

However, the boom of the 6-element VHF TV antenna is considerably longer than that for the DAB+ antenna and overall it is quite a lot larger and heavier and it would have a lot more windage when used in vertical mode. You could make the boom from 25mm or larger square tubing but using a non-metallic mast is probably the simplest and best option.

If you use a timber mast, we suggest it must be at least 35mm in diameter, made of durable hardwood and painted to preserve it from weathering.

Currawong has hum in one channel

I have finally got my Currawong stereo valve amplifier (November 2014-January 2015; siliconchip.com.au/Series/277) up and running.

However, I've got hum in the left channel which is not influenced by the volume control and it gets worse if I remove LK4. I have no hum whatsoever in the right channel, regardless of whether LK5 is fitted. Is there a fix for this? (C. B., Gillieston Heights, NSW)

● This could have a number of causes, including a faulty solder joint or bad valve pin connection to the socket, faulty valve or bad wiring. It could also be caused by unusually high levels of hum pickup from wiring near the transformer.

We suggest you try temporarily removing V1 and connect a clip lead across the 100kΩ resistor that goes to pin 6 on V1. This resistor is to the right of V1 (the right-most of three there). Be careful because HT is applied to this resistor.

Make sure the clip lead (or whatever you use to short it) has sufficient insulation and don't touch it when power is applied.

This will mean that there is no signal at the input of V2. If the hum goes away, that suggests a problem with V1 or its socket soldering or the surrounding circuitry. If you still have significant hum then try removing V2. That will eliminate the signals driving V7 and V8. If that fixes it, then V2 or an associated component is suspect.

If none of that helps, rotating the transformer may also reduce or eliminate the hum. Keep in mind that the transformer lead lengths may limit the amount of rotation possible and make sure to loosen the mounting bolt before rotating and tighten it again when you have finished.

Whatever changes you make, switch off the power, unplug the unit and make sure the HT capacitors have discharged before removing the insulating panel to work on it.

Note: we received subsequent correspondence that the cause of the hum was due to the pins in the left-hand speaker connector not being a tight enough fit into the socket. Replacing the pluggable terminal block on that side eliminated the hum.

Jacob's Ladder does not work

My 10-year old son built your Improved Jacob's Ladder project from the February 2013 issue (siliconchip.com.au/Article/2369). It didn't work, so we built another one, with the same result. There just doesn't seem to be any power to either one, no matter what we do. (B. B., via email)

● If there is no power then either the 10Ω resistor supplying the circuit is open-circuit or there is a short on the regulator output. Check that IC1 is oriented correctly. Check that there is 12V at the input to REG1 and 5V at its output.

Make sure the ignition coil connections are correct, with the coil primary negative terminal to the coil primary negative on the PCB and the coil primary positive to the +12V via a 10A fast-blow fuse. It is possible that you have connected the coil primary positive to ground instead.

Having checked all this, adjust the dwell as described in the middle of the left-hand column on page 65.

Curing on/off thump in the Active Crossover

I built the 3-way Active Crossover from the September and October 2017 magazines (siliconchip.com.au/Series/318) and really like it. It works beautifully.

The only problem I have is that if the speaker amplifiers are left on and turned up when the crossover is pow-

ered off or on, it can produce a big "thump" in the output. I have to make sure the main amp volumes are down before powering on/off the crossover. It sounds like a capacitor charging; sometimes this happens with subwoofers.

I was wondering whether John Clarke might know how to mute this output pulse somehow. (B. S., Torrens Park, SA)

● The switch-off thump can usually be reduced if the positive and negative supplies both decay at the same rate. The 15V supplies can be balanced to discharge at a particular rate with a resistor across one of the 15V regulator outputs (ie, between the output and GND). You would need to measure which supply rail falls the slowest, positive or negative, and add a resistor across that output.

The resistor value will need to be adjusted so that the decay rate matches the other supply. An oscilloscope monitoring both supplies will reveal the difference in voltage fall rates.

Switch-on (and also switch-off) thumps can generally also be reduced by adding a 100nF capacitor across each of the low voltage power switch terminals. That provides an amount of switch contact de-bounce and also provides some quiescent current to the power supply.

Having said that, normally the Crossover should be switched on and off at the same time as the power amplifiers (eg, using the same mains switch), thus allowing the thump removal circuitry in the amplifiers or corresponding speaker protectors to solve the problem.

10MHz GPS-locked frequency standard

I have had my Amateur Radio License now for 57 years and have always enjoyed reading electronics magazines, starting with "Radio & Hobbies". Haven't we seen a lot of changes since then? In recent times, I have enjoyed the Micromite projects, having built three of them now.

With Amateur Radio equipment getting more exotic over the years, have you ever described a 10MHz GPS-locked frequency standard? With amateurs going higher in frequency, into the microwave bands, it's becoming critical to have an accurate standard to work with.

I have a Marconi frequency generator that goes up to 1500MHz and it would be nice to be able to lock it to an accurate standard. Like most, it has a socket on the rear to attach a reference oscillator.

Please keep up the good work with the magazine. (T. H., Kingston, SA)

● Please see our GPS-based Frequency Reference project in the March, April and May 2007 issues and the subsequent update in the September 2011 issue: siliconchip.com.au/Series/57

Discrepancies in Touchscreen Altimeter

Is it correct that the AM2302 temperature and humidity sensor supplied for the Touchscreen Altimeter/Weather Station (December 2017; siliconchip.com.au/Article/10898) is not mounted on the circuit board as shown on photos per the article in the December issue?

The small PCB appears to contain some additional components and only three connection pins.

Anyway, I proceeded to finish construction using the DHT22 datasheet pinout and that function seems to be working OK. However, there are some discrepancies with the Altimeter function.

In the magazine, the opening screen reads "metres above GND" while my screen shows "metres above QNH" What is QNH? Similarly, on the CHANGE MODE OR UNITS screen, the magazine shows "GROUND REFERENCE" while my screen shows "Input QNH Reference".

When the "Input QNH Reference" button is touched, a numeric keypad is shown. I thought the keypad expected an input referring to the actual location altitude variation.

However, when I entered a negative value (my location was about 25 metres lower than the altitude shown), the system crashed showing 00.00 metres and I could get no response from screen touches. I had to reset the Micromite.

I did make a couple of structural alterations to allow the unit to be placed on a shelf laying on its side; I mounted the power switch on the front panel to the right of the touchscreen and instead of using screws to secure the battery holder, I used hot melt glue.

I have recently built Kelvin the Cricket which entertained my whole family over the Christmas holidays.

Keeping short links for posterity

In recent times, you have started publishing short links to internet content which work through your own web presence, which is grand for now. It would be more useful for people accessing the online version rather than the paper version I guess.

I'm thinking about what happens should there be a disaster similar in nature to what happened to EA, ETI, RTV&H and every other relevant magazine ever published (or so it seems). Should the business cease to exist or the website be altered in some way (eg, change of name), then all those short links become useless.

Have you considered providing a summary of the short links and the actual URL being referenced, perhaps as an ever growing list, on an annual basis (January to December inclusive and resetting each January), or per issue, within the printed edition at least? It might take a similar form to the advertisers' index, normally facing the inner back cover.

It's just an idea but it would hopefully not cost much and would make the paper magazine useful beyond the life of your current website. I find I refer back to 1980s and 1990s EAs and ETIs at times.

If they had used short links then, they would be useless now. (P. G., Ardross, WA)

● Even if SILICON CHIP magazine ultimately became financially nonviable and ceased publication (perish the thought), the website could be spun off and operated as an independent entity.

Having said that, you can get an up-to-date list of all short links from www.siliconchip.com.au/l/ and you can download them in CSV file format at www.siliconchip.com.au/l/csv

Mind you, even the full links have a finite life. In fact, the most common reason why short links fail is that the original link no longer works and probably this will be because the particular website no longer exists.

Every time he chirped the crowd went quiet to hear what the temperature was. The children learnt to count by fives as well. Kelvin regularly compares notes with the Altimeter/Weather Station and they are usually within about 1.5°C of each other.

I really appreciate SILICON CHIP publishing articles on the Micromite as I do not want to go down the Arduino or Raspberry Pi trails. I will stick with Micromite and PICAXE for economy and simplicity.

I am more than happy with using BASIC coding as I can make some sense of it. Thank you all for a great read being highly educational and entertaining. (S. S., Barrington, NSW)

● There was some confusion over the DHT22 sensor as the circuit diagram shows a "bare" DHT22 (with the pins labelled correctly but in the wrong order!) while the overlay diagram and photos show a DHT22 mounted on a small breakout board with two additional components.

We sell the bare DHT22 but as you point out, it can be made to work with the correct wiring. We're publishing errata in this issue regarding these discrepancies.

We explained the addition of the QNH feature post-publication in the Mailbag section of the January 2018 issue (page 4). According to Wikipedia, QNH is "a Q code indicating the atmospheric pressure adjusted to sea level".

When you bring up that keypad, enter the atmospheric pressure at sea level at your location for corrected altitude readings.

This is available to pilots in flight over the radio, allowing them to correct their altitude readings before landing.

The software presumably can't handle the entry of a negative barometric pressure. You can set the software back into the original mode shown in the magazine by selecting "MSL Reference" mode via the menu.

Altimeter chip does not need reprogramming

I received your kit for the Touchscreen Altimeter (December 2017; siliconchip.com.au/Article/10898) early this week.

Today the January 2018 edition of the magazine arrived. I saw the comments in Mailbag on page 4 about the revised software. I had wondered about the absence of a QNH adjustment function.

I am an ultralight pilot and am interested in using the project in my plane to compare with the inbuilt altimeter as a matter of interest.

However, I have currently no computer and have no experience in program loading, therefore can't update the software myself. Can I send the chip back to be reprogrammed with the updated version of the software? I have not removed it from its package at this stage.

Please advise on how we can solve this dilemma. I am happy to reimburse you for any shipping costs.

My second question concerns the Elecrow charger module. I see no reference to the solar panel voltage in the article. I assume the input voltage is 12V DC. I keep the plane's battery charged with an 80-watt solar panel/charger controller whilst it is not in use. Can I connect this Elecrow board to that solar panel?

● No software update is required. All chips supplied for the Altimeter project have the QNH feature mentioned in Mailbag.

Are brushless DC motors similar to induction motors?

In reading the Lathe-E-Boy project (January 2018; siliconchip.com.au/Article/10933) and subsequently the earlier 1.5kW Induction Motor Speed Controller articles (April-May 2012; siliconchip.com.au/Series/25), maybe the penny has dropped!

We are now surrounded by "brushless DC" power tools, electric skateboards with "brushless DC" motors, battery electric garden equipment, inverter air conditioners and fridges and I suppose there are more.

Having recently repaired a Fujitsu inverter aircon which used a Fairchild FSBS10CH60 IGBT motor controller and comparing the circuit with the 1.5kW Induction Motor Speed Controller, the power circuitry is almost identical in design philosophy.

The associated motor winding connection explanation makes more sense than that which I read (not from Fujitsu) regarding inverter-driven aircons which mentioned "3-phase DC motors" and showed a schematic with a star connected motor and no connection to the common winding.

A lot of this jargon seems a bit esoteric but when read in the light of the motor explanation in the April 2012 issue on the 1.5kW Induction Motor Speed Controller, it seems that all the motors are only size variants of a delta-wound 3-phase motor connected to a suitably-sized IGBT and controlled by a fast digital switcher for speed control. Is that right? (P. C., Ormiston, Qld)

● The driving circuitry for brushless DC motors and 3-phase induction motors is quite similar. They both typically have a number of driven coils which is usually a multiple of three.

The difference is that the rotor field of a BLDC motor is provided by permanent magnets while the rotor field of an induction motor is induced by the rotating magnetic field of the stator coils.

For current to be induced in the rotor conductors of an induction motor (whether it is off squirrel cage construction or has wound coils), there must be some "slip" (ie, a delay between the rotating field of the stator and the induced field in the rotor) in an induction motor, whereas a BLDC motor will be essentially synchronous.

Speed control of an induction motor requires varying the voltage and frequency applied to the windings and while there are various ways to do this, high-frequency PWM using IGBTs in bridge circuits is the most practical method and it's how almost all these controllers work.

Whether the motor is delta-wound or star-wound really only affects the voltage required. The way the windings are driven is essentially identical.

A star-wound motor does not require a neutral connection to the common windings; without one, a "virtual neutral" exists.

The charger module expects a solar panel voltage of around 5-6V. There are numerous small panels available with an open-circuit voltage of around 6V, including one that we sell in our Online Shop, Cat SC4339.

Note that you will probably need to wire more than one of these small panels in parallel to supply sufficient current to operate the unit.

By the way, please check the errata for that project on page 104 of this issue regarding the wiring of the DHT22 temperature and humidity sensor.

High-Energy Ignition System with 6V battery

I want to build the Jaycar KC5513 High-energy Electronic Ignition kit (based on your November-December 2012 design; siliconchip.com.au/Series/18) for an old motorcycle with a 6V system using a standard points arrangement.

Does the kit need any modification to cope with a 6V rather than 12V system?

Harley Davidson 1927 J Models used points without a distributor but a dual-lead coil and were thus a "wasted spark" arrangement. I don't see any issues using your ignition system on those old V-Twins. (K. D., via email)

- That ignition system can be used at 6V. The LM2940 is a low-dropout regulator and it will be OK with a 6V battery.

However the battery voltage will inevitably drop below 5V during cranking (if there is a starter motor) and will reduce the available spark energy until the engine fires up. Make sure the points are correctly gapped otherwise starting may be problematic.

Frequency Switch kit is not working

I have a Jaycar KC5378 Frequency Switch which I cannot get to work. It's based on the article you published in the June 2007 issue and also in the book Performance Electronics for Cars (siliconchip.com.au/Article/2261).

Having built it, I powered the unit up and connected a voltmeter between ground and TP1. There was no voltage present and adjusting VR1 did not affect this.

If I rotate VR2 anti-clockwise, the relay will latch; then clockwise it will unlatch. However, any input method I have tried will not trigger the relay. Please advise of any checks I could do to rectify this. (A. C., Swan Hill, Vic)

- If there is no voltage at TP1, check that there is 7.4V at the cathode (K) of diode D2 and 8V at the output of REG1. Varying VR1 will not affect the TP1 voltage.

It appears that VR2 does change the TP1 voltage since you can get the relay to switch on and off with adjustment.

If you apply an AC signal to the input, the voltage at pin 4 of IC1 should rise; the higher the signal frequency, the higher the voltage at pin 4. It's this relationship which VR1 adjusts. VR2 simply sets the threshold where the relay switches on or off.

Adapting 12V battery charger for 24V

I want to build the Jaycar KA1795 12V Battery Regulator kit, based on the article published in *Electronics Australia*, July 1997.

I want to use it to charge a 24V 4.5Ah lead-acid battery.

Could you please suggest which component values need to be changed and/or upgraded to give the correct regulated voltage.

I am using an Arlec battery charger

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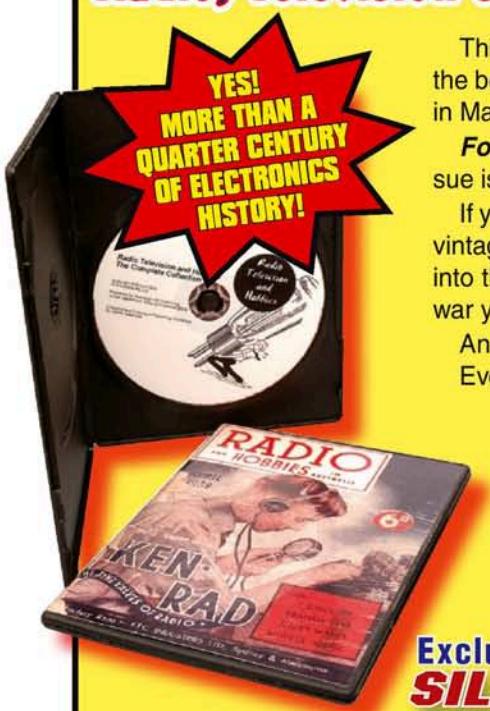

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with the 2 x 12V windings in series, giving about 28VAC. (B. C., Dungog, NSW)

● We suggest that you change the following resistors: R5 to 12kΩ, R7 to 1.2kΩ and R8 to 68Ω 5W. Note that we cannot guarantee that these mods will work; they might need tweaking.

SC200 Amplifier questions

I have been reading the article on building the SC200 Amplifier which was re-published in the January 2018 issue of EPE Magazine. The power output transistor FJA4313 appears to be unobtainable. I can't find a supplier that stocks this transistor.

Also, there is also a mistake in the article. ±56.6V is derived from 40-0-40 AC secondary transformer, not 45-0-45 AC; this would give ±63.6V.

LED1 is specified as SMD 3216/1206 blue and there are different version of this with 20mA or 30mA forward current.

The typical forward voltage ranges from 3.2V to 3.6V. Which one is the correct LED and does it matter? (A. W., Wimborne, UK)

● FJA4313OTA is available from Digi-Key (Catalog code FJA4313OTU-ND) or as part of a set of hard-to-get parts from our SILICON CHIP Online Shop (Cat SC4140). You are right, the transformer should have been specified as 40-0-40V; not 45-0-45V.

LED1 is supplied with around 2mA so any blue LED of that size should be fine. The forward voltage is not important as it's supplied from a constant current source.

High Energy Ignition systems with points

I have a 1978 Datsun 200B with points. Will the High-Energy Ignition System you published in the November and December 2012 issues (siliconchip.com.au/Series/18) work with points? (W. O'D., Cartwright, NSW)

● All of our High Energy Ignition systems can be used with points as well as reluctor, Hall effect and optical triggers.

Will SC200 transformer be overloaded at 200W into a 4Ω load?

I am an EPE subscriber emailing from England. I have recently thoroughly enjoyed the brilliant SILICON CHIP SC200 amplifier constructional project published in EPE over the last three months. Congratulations to both Nicholas Vinen and Leo Simpson for yet another job well done.

However, I have a technical query which has been troubling me concerning the power supply for this project. My calculations imply that the transformers specified for this project are underpowered. If there is an error in my calculations below, I would be pleased if you could correct me.

A 300VA, 80V transformer is capable of supplying a maximum current of 300 ÷ 80 = 3.75A RMS. When the SC200 is supplying the maximum stipulated 135W into an 8-ohm load, $135W = 8 \times I^2$ and therefore I = 4.1A.

However, in the push-pull amplifier output stage, 4.1A is only drawn from each secondary for half the time. Therefore, the average DC current drawn by each half of the output stage is 2.05A.

Now, there is a 1.7 multiplication scaling factor from the DC load current to the transformer AC RMS current for this configuration of power supply.

Therefore $I_{RMS} = 2.05 \times 1.7 = 3.5A$ which is less than the 3.75A RMS available from a 300VA transformer. All appears well for an 8-ohm load. However, going through the same calculations for the rated 200W, 4-ohm load,

$200W = 4 \times I^2$ gives I = 7A, which is on for only half the time in each half of the transformer secondary. Therefore average DC current in each half of the output stage is 3.5A. Multiply by the 1.7 scaling factor, 3.5A × 1.7 = 6A RMS, which is much more than the 3.75A RMS available from a 300VA transformer.

It appears to me that a 500VA (80V @ 6.25A) transformer is required to supply 200W into 4-ohms.

If the 1.7 scaling factor is omitted then the transformers specified in EPE appear to be powerful enough. Has Nicholas omitted to include the 1.7 scaling factor in his calculations?

Likewise, by similar calculations, for the low-power version of the PSU/amplifier, it appears to me that a larger transformer is required to supply the rated power into four ohms, ie, larger than the specified 160VA transformer.

I would be very thankful if you could consider my theory and point out to me if and where I have made an error in my calculations. This has been puzzling me! I suspect that I'm missing something. (C. H., London, UK)

● Strictly speaking, you are correct. When delivering 200W into a resistive load, the amplifier will draw more than 300W. But even though we state that the amplifier can do this (and it can), the assumption is that the normal load will be a loudspeaker and therefore partly inductive rather than purely resistive.

Second, unless you intend using the amplifier with a constant sinewave signal (perhaps driving a vibration table), the actual power delivered to the load will be substantially less.

Third, normal program signals are complex and typically have a dynamic range of more than, say, 30dB.

Putting it another way, the full power duty cycle will be quite low and the average power drawn by the amplifier, even when driven to the point of clipping on audio programs, will be quite small; perhaps only a few watts. So in practice, for normal domestic audio use, the 300VA transformer is quite adequate. In fact, a 300VA transformer would be quite adequate for a stereo pair of these modules.

On the other hand, if you intend using the amplifier module with a 4-ohm loudspeaker load for music instrument applications, particularly for bass guitar or electronic organ, we would recommend going for a 500VA transformer.

As a final comment, if you did intend to drive the amplifier for a long-term continuous output of 200W, we'd be more concerned about the ratings of the main filter capacitor, the output power transistors and their heatsinks and the risks of overheating than the transformer. SC

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Coming up in Silicon Chip

Rohde & Schwarz RTM3004 oscilloscope review
We take an in-depth look at one of Rohde & Schwarz's newest scopes, the RTM3004, with 1GHz bandwidth, 5GHz sampling, 10-bit vertical resolution, 16 digital channels and an 80Msample memory.

Facett Hearing Aids from Blamey Saunders
Ross Tester reports on his experiences with the latest set of hearing aids from leading Australian supplier Blamey Saunders hears.

Introduction to programming the Cyprus CY8CKIT
This low-cost module incorporates a 32-bit microcontroller and a set of reprogrammable analog circuitry which can be used for a wide range of tasks. We show you how to use the free Integrated Development Environment.

Radiant Heater Controller
It will be winter in just a few months. Staying comfortable at night can be a challenge. This new Heater Controller design takes care of that, adjusting the heating power while you are sleeping to provide gentle heat without any clicking thermostats or blinking lights which may wake you up.

El Cheapo Modules – RF attenuators
Jim Rowe describes a programmable, 63-step, 4GHz RF digital step attenuator module with a range of applications. Plus he also looks at a fixed four-range DC-4GHz attenuator

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The April 2018 issue is due on sale in newsagents by Thursday, March 29th. Expect postal delivery of subscription copies in Australia between March 29th and April 13th.

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Notes & Errata

Lath-e-Boy High-power Lathe Controller, January 2018: the wiring colours shown in the photos on pages 40, 41 and 43 and in the lower-right corner of the circuit diagram on page 39 are not safe. The four wires to the induction motor should be colour coded red, white, dark blue (from pin 2 of CON7 to the motor) and brown. Green/yellow striped wire must be used for earthing the motor frame (and only for earth!).

Touchscreen Altimeter and Weather Station, December 2017: there are some inconsistencies and ambiguities between the circuit diagram (Fig.1), sensor wiring (Fig.3) and parts list, regarding the temperature and humidity sensor. The circuit diagram on page 25 showed a bare DHT22/AM2302 sensor with correctly wired pins, however, pin 4 was shown on the left side of the device and pin 1 on the right, the opposite of how they are numbered on the physical module.

Also, the module shown in Fig.3 and the accompanying photo is mounted on a small breakout board with two extra components which were not shown on Fig.1 and not mentioned in the text or parts list. The sensor we supply does not come with the breakout board.

The circuit diagram in the online edition has been corrected to show the two extra components. If the sensor you've purchased does not come on a breakout board, simply solder a 100nF capacitor between pins 1 and 4 of the DHT22/AM2302 and a 1kΩ resistor between pins 1 and 2. Note that the 1kΩ resistor could just as easily be fitted between the +5V and pin 21 (DATA) connections on the BackPack module.

High-Power DC Fan Speed Controller, January 2018: the IPP80N06S2L-07 Mosfet is listed in the parts list as being in a TO-92 package but it is actually in a TO-220 package.

Arduino Mega Box Music Player, February 2018: the Arduino Uno and Mega do not share the same SPI pin connections. Pins 50, 51 & 52 must be connected by flying leads to digital pins 12, 11 & 13 respectively before the SD card will work on the Mega.

SC200 Audio Amplifier, January-March 2017: the power supply is mistakenly listed as 45-0-45V to provide ±57V on page 32 of the January issue and page 85 of the February issue. The transformer is actually 40-0-40V as described in the parts list and circuit diagram in the March issue where the power supply is described in full.

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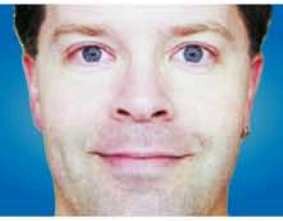

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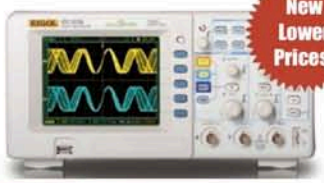

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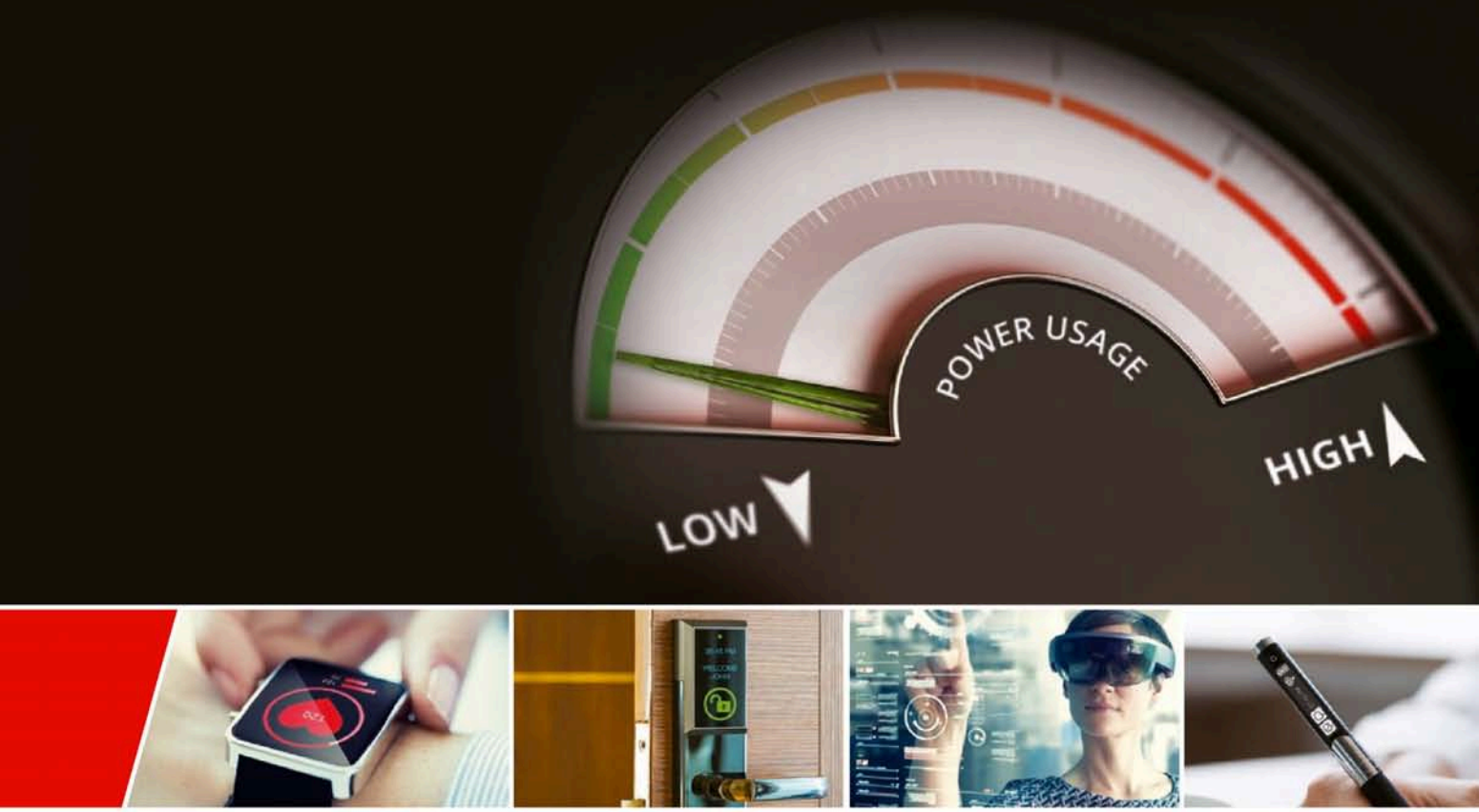

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